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# PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



IN THIS ISSUE: Penn—*Pupae of Mosquitoes of  
New Guinea* • Wentworth—*Shift of Trade Winds*  
• Fosberg—*Atoll Vegetation and Salinity* • Uti-  
nomi—*Cirripeds from Ogasawara Islands* • NOTES

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[Continued on inside back cover]

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# The Pupae of the Mosquitoes of New Guinea

GEORGE HENRY PENN<sup>1</sup>

## INTRODUCTION

MANY FAUNISTIC PUBLICATIONS on mosquitoes dismiss the pupal stage with a general account of its external morphology and a few remarks to the effect that the pupa is of no practical significance in taxonomic work. This study of the pupae of New Guinea mosquitoes demonstrates, however, that pupal characters are relatively constant for any given species and that the examination of pupae is a valuable adjunct not only in the taxonomy of mosquitoes, but also in throwing light on some of the puzzles of species relationships and evolutionary trends within the family Culicidae.

Since the pupal stage is ordinarily of short duration it might be assumed that little change would occur in pupae in evolutionary processes, and such is probably the case. For example, the pupae of most species of the genera *Aedes* and *Culex* are more readily grouped into their respective subgenera than into their respective genera. On the other hand, specific differences seem to have been accentuated, and pupae of very closely related species, such as *Uranotaenia nigerrima* and *U. papua*, *Aedes kochi* and *A. wallacei*, are more easily separated than are the adults.

With the exception of a paper by Hill (1925) nothing of significance had been published prior to World War II concerning the pupae of New Guinea mosquitoes, and only a few papers which include pupae of the indigenous mosquito fauna have appeared since the war.

Of the 167 species which are autochthonous to the Australasian Region, the pupal stage of 27 has been fragmentarily described or figured

in papers by Hill (1925: 62-77) and by Taylor (1929: 271-278). Other species found also in the Oriental Region and Wallacea, including *Anopheles barbirostris*, *An. karwari*, *An. subpictus*, *Megarhinus splendens*, *Harpagomyia genurostris*, *Mansonia africana*, *M. uniformis*, *Aedomyia catacticta*, *Aedes auranitus*, and *Culex sitiens*, have been described, some of them rather completely, by such workers as Senevet (1931: 38; 1932: 209, 223), Crawford (1938: 39, 89), Baisas (1936a: 74; 1936b: 212; 1938: 181), Barraud (1931: 1131), De Meijere (1911: 164), Edwards (1941: 384, 417), and Edwards and Given (1928: 341). The species of cosmopolitan distribution, such as *Aedes aegypti*, *A. vexans*, and *Culex fatigans*, have received attention by several workers in different parts of the world.

Sixty-eight of the 196 species of mosquitoes recorded from New Guinea by Bick (manuscript) are now known in the pupal stage and are included in this paper. Thirty-six species are here fully described and illustrated for the first time. Thirty-two species have been variously described previously by others. I have redescribed and illustrated six of these; the descriptions of the remaining 26, 16 of which were only very poorly described and not available for examination, have been quoted without change from original sources.

An opportunity to collect material for this study was presented when Dr. George H. Bick and the writer were placed in charge of U. S. Naval Malaria Control Teams and assigned to duty in the southwest Pacific. Our combined collecting efforts, pooled after 15 months in New Guinea, amounted to 1,508 separate collections of larvae and pupae. Nine localities along the northern coast of New Guinea from

<sup>1</sup>Department of Zoology, The Tulane University of Louisiana, New Orleans. Approved for publication October 28, 1947.



Milne Bay on the east to Amsterdam Island on the west are represented in the collections. The localities are the villages of Gamadodo ( $10^{\circ}25'$  S,  $150^{\circ}22'$  E), WagaWaga ( $10^{\circ}25'$  S,  $150^{\circ}25'$  E), Hilimoi ( $10^{\circ}25'$  S,  $150^{\circ}29'$  E), and KanaKope ( $10^{\circ}30'$  S,  $150^{\circ}40'$  E) on the south shore of Milne Bay in Papua; Morobe ( $7^{\circ}45'$  S,  $147^{\circ}35'$  E), Draeger Harbor ( $6^{\circ}35'$  S,  $147^{\circ}50'$  E), and Saidor ( $5^{\circ}40'$  S,  $146^{\circ}30'$  E) in Northeast New Guinea; and Mios Woendi ( $1^{\circ}15'$  S,  $136^{\circ}20'$  E) and Amsterdam Island ( $0^{\circ}20'$  S,  $132^{\circ}10'$  E) in Netherlands New Guinea.

Representative samples of each of the collections were selected for rearing in isolated containers and the larval and pupal exuviae were thus associated with the adults.

The material has been divided among several institutions. The largest lot has been de-

posited in the United States National Museum, and representative series of associated larvae, pupae, and adults have been placed in the collections of Cornell University at Ithaca, New York, and the University of Queensland, Brisbane, Australia.

Magnification of figures is indicated by the lines beside them which represent 0.5 mm.

*Acknowledgments:* I am particularly indebted to Dr. George H. Bick of Tulane University, who collected and contributed much of the material used in this study. The men of our units, the 25th and 28th Naval Malaria Control Teams, were of invaluable assistance in carrying on the surveys of the several bases; for their initiative and interest in the work, I am grateful to Alfred C. Bodenman, William L. Schmid, Ralph E. Geiger, Jack P. Gallagher,

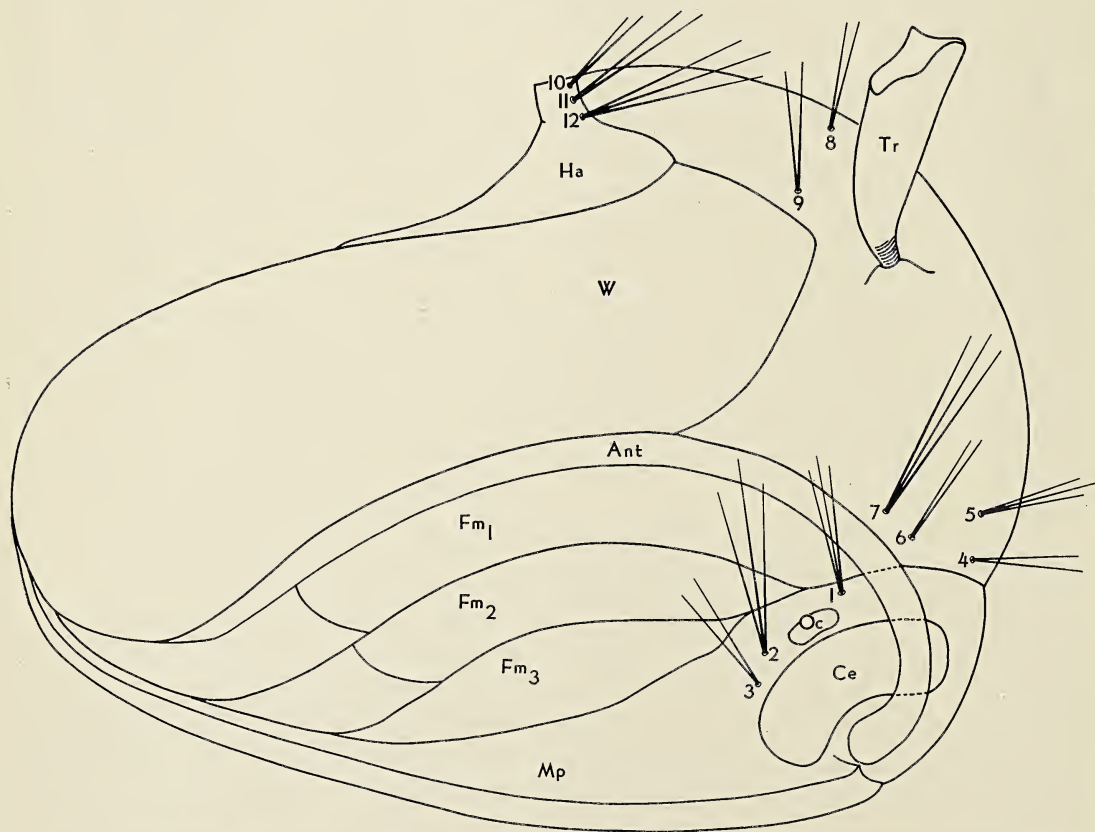


FIG. 1. Generalized cephalothorax of pupa in lateral view. Ant, antenna; Ce, compound eye; Fm 1, 2, 3, femora of pro-, meso-, and metathorax; Ha, haltere; Mp, mouth parts; Oc, ocellus; Tr, respiratory trumpet; W, wing pad.

M. A. Greenblatt, William W. Bonds, Harold W. Dorman, A. S. Griswold, James E. Surgenor, William T. Whitfield, Peter B. Tompkins, and Otis L. Andrews.

Dr. Alan Stone of the U. S. Bureau of Entomology and Plant Quarantine confirmed the determinations of most of the species; Professor F. A. Perkins and Miss Elizabeth N. Marks of the Entomological Laboratories of the University of Queensland generously assisted in the identification and storage of materials collected during the early months of our stay in New Guinea.

Finally, I am especially grateful to Dr. Robert Matheson of Cornell University, who directed and encouraged the study of this problem and whose friendly interest and counsel will long be remembered and appreciated.

#### FEATURES OF TAXONOMIC IMPORTANCE

Although the first attempted identification of mosquito pupae utilized the arrangement and branching of the abdominal setae (Mitchell, 1907: appendix) it was not until Macfie (1920: 161–169) published his account of the pupal chaetotaxy of *Aedes aegypti* that the value of setae in the classification of pupae was recognized.

Most of the early workers based their classifications on gross structures such as the shape and size of the respiratory trumpets and natatory paddles. Thus Banks (1908: 235–258), Wesche (1910: 7–50), Jacobson (1911: 158–161), De Meijere (1911: 162–167), Howard, Dyar, and Knab (1912–1917), Ingram and Macfie (1917: 73–91; 1919: 59–69), Wigglesworth (1920: 59–68), and Hill (1925: 62–77) described or figured mosquito pupae from various parts of the world.

Modern taxonomy of mosquito pupae utilizes all of the morphological features and chaetotaxy which may be of use in determining each species. The following discussion and table will elucidate the characters and terminology used in the present paper.

#### Morphology

The general appearance of a mosquito pupa is like a comma with an exaggerated dot, the dot being the head and thorax fused into a cephalothorax, the tail of the comma being the abdomen. Generally the size of the pupa corresponds to the size of the imago.

**CEPHALOTHORAX.**—The head is marked by the appearance of the compound eyes of the adult near the anterior margin (Fig. 1, Ce) and the smaller pupal eyes just posterior to them (Fig. 1, Oc). The mouth parts (Fig. 1, Mp) can be seen closely compressed and developing in the central part of an ovoid shield which covers the front and sides of the cephalothorax. The antennae (Fig. 1, Ant) extend from the sides of the epicranial region and run outward to the sides of the cephalothorax, one beneath the anterior margin of each wing.

The mesothorax is marked by the respiratory trumpets (Fig. 1, Tr), which provide the only opening in the integument of the pupa. The spiracular opening is always at the base of the trumpet in the Culicinae, but may be either at the middle or nearer the apex in the Chaoborinae. Each trumpet (Fig. 2) is divided into a tubular portion, the meatus, and an open funnel-shaped portion, the pinna. The meatus is often plainly divisible into a proximal tracheoid portion provided with numerous concentric ridges, and a distal reticulate portion, the surface of which is covered by a fine network.

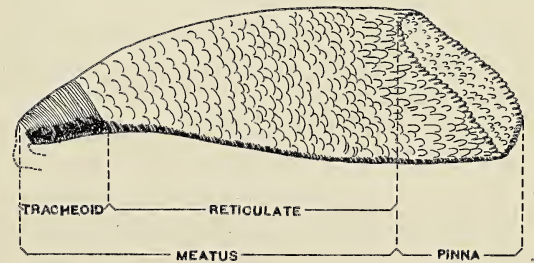


FIG. 2. Generalized trumpet of culicine pupa.



pinna may be circular, oval, or quite irregular with a slit-like projection. The proportions of these parts and the shape of the opening are fairly constant and hence are useful in taxonomic work.

The wing-pads (Fig. 1, W) appear as flat oblong plates arising behind the bases of the trumpets and extending caudad and ventrad.

The metanotum is readily distinguished as a plate set off by sutures from the rest of the cephalothorax cephalad of the first abdominal tergite. The metanotum consists of a pair of triangular plates enclosing the halteres (Fig. 1, Ha) and connected dorsally by a narrow bridge.

**ABDOMEN.**—The abdomen is dorso-ventrally compressed and exceedingly flexible in this direction. It is the only part of the pupa in which segmentation is readily recognizable. Each segment has a sclerotized tergum and sternum, and successive segments are joined shingle fashion by soft intersegmental membranes.

Nine segments are visible dorsally (Fig. 3). The first eight correspond in general, but segments I and VIII are usually smaller and modified for articulation with the metanotum and paddles respectively. Segment I further differs from the others in the sclerotization of its tergum, being conspicuously thicker along the cephalic and lateral margins, the center being thinly sclerotized and bearing the float-hairs (Fig. 3, Fl). The center is reinforced by a pair of oblique antero-laterally projecting strongly sclerotized ridges and a heavily sclerotized bridge which extends from the cephalic margin to the caudal margin of the tergum.

The median caudal projection of the eighth tergite which overhangs the paddles probably represents the ninth segment fused immovably to the eighth.

The median caudal projection of the eighth sternite which lies ventrad of the paddles is interpreted as the tenth segment since it contains the developing external genitalia of the imago.

Thus, the paddles are attached to segment

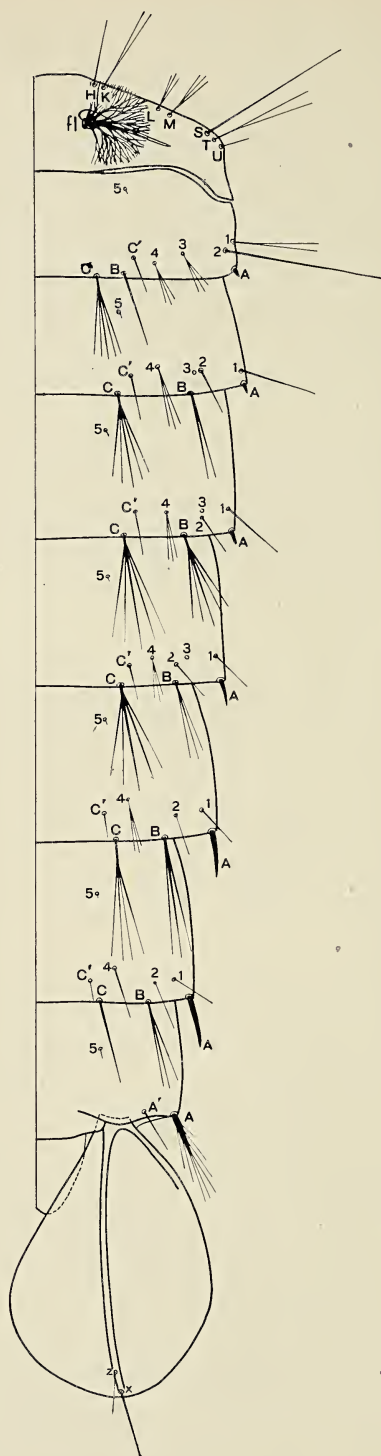


FIG. 3. Generalized abdomen of anopheline pupa in dorsal view (right half).

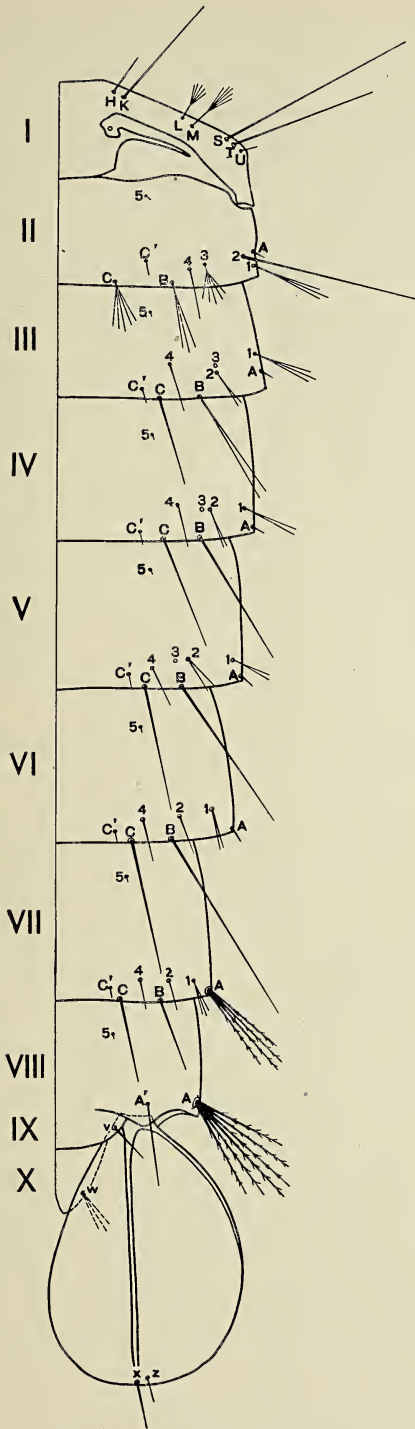


FIG. 4. Generalized abdomen of culicine pupa in dorsal view (right half).

VIII in a groove along the caudal edge of the segment. The paddles articulate freely only in a lateral direction, and as a rule are broadly oval, dorso-ventrally flattened plates. They are usually strengthened by a thickened outer buttress, which extends partially around the lateral margin from the base, and by a median thickened midrib which extends from the base to the apex; the medial and caudal margins are never reinforced by a buttress. These latter margins may, however, be either entire, denticulate, or fringed with hairs along part or all of their extent. The hairs forming the fringe are always mere processes from the edge of the paddle without articulated bases. Near the apex of the paddle one or two setae may be present. These are usually designated as the terminal seta (Figs. 3 and 4, x) and the accessory seta (Figs. 3 and 4, z). The shape of the paddle, presence or absence of the terminal and accessory setae, and the nature of the margins have long been recognized and used as valuable features in taxonomic work.

*Chaetotaxy*

Macfie (1920: 161–169) stated that the pupa of *Aedes aegypti* is furnished with 100 pairs of setae, 12 pairs of which he found on the cephalothorax, and 88 pairs on the abdomen. In addition, Macfie determined that the chaetotaxy varies with right and left sides of the same individual, but that it is the same for pupae of different ages and that neither sex exceeds the normal variations of the species.

Several different systems of designating pupal setae have evolved since Macfie's paper. All of them, however, are based fundamentally on Macfie's system. These include the systems of Senevet (1930: 297–382), Baisas (1936: 65–84; 1938: 175–232), and Edwards (1941: 354–428). Rozeboom and Knight (1946: 95–131) recently originated an entirely new system for the abdominal setae only.

The following generalized description of pupal chaetotaxy follows mainly the modified system of Baisas.



**CEPHALOTHORAX.**—There has been little deviation from Macfie's classification of the cephalothoracic setae, probably because they show so little variation in position among the genera of mosquitoes. The setae are illustrated in typical positions in Figure 1, and are described as follows:

*Postocular* (circum-ocular of Macfie): Three setae located on the head shield close to the posterior border of the eye; 1 upper, 2 median, 3 lower.

*Anterothoracic*: Four setae located in the triangular area between the anterior margin of the cephalothorax and the upper border of the antenna as it sweeps backwards; 4 lower anterior, 5 upper anterior, 6 lower posterior, 7 upper posterior.

*Dorsal*: A single seta (8) located between, a little behind, or far behind, the trumpets.

*Supra-alar*: A single seta (9) located above the root of the wing.

*Metanotal* (posterothoracic of Macfie): Three setae located on the bridge of the metanotum: 10 internal (O of Senevet, Baisas, and Edwards), 11 median (P of Senevet, Baisas, and Edwards), and 12 external (R of Senevet, Baisas, and Edwards).

**ABDOMEN.**—In attempting to homologize the setae of anopheline, culicine, megarhinine, and sabethine pupae I have been able to follow the reasoning of Baisas (1938: 175–232) almost completely for all except the dorsal setae of segment II. This is the most difficult segment to fit into the scheme of the abdomen as a whole because of the shifting in position of some of the setae. Rozeboom and Knight (1946: 95–131) considered that the setae of segment II were not entirely homologous to those of III–VII when they stated that not all segments have all the setae, and Baisas (1938: 175–232) and others apparently failed to find all of the setae on segment II. However, I have found the full complement of setae on segment II and consider the differences from other segments as of position only.

Seta A is present as a spine or simple hair on

segments II through VI of all mosquito pupae with the exception of the tribe Megarhinini, the pupae of which will be discussed in a separate paper. On segment II, seta A is a minute simple spine or hair on the lateral margin usually somewhat anterior to the postero-lateral corner (Figs. 3, 4). With this as a starting point and working toward the mid-dorsal line of the tergite we find seven setae more or less near to the posterior margin, and one (seta 5) near the anterior margin. The larger two of the posterior seven, usually nearest the posterior margin, are designated as B and C, and the others a little more anterior are taken in sequence from lateral side to mid-dorsal line as setae 1, 2, 3, 4, and C' respectively. The position of C' varies somewhat, but it is usually a small, simple, more or less, spine-like seta placed either just laterad of, or just mesad of, B.

There is usually no difficulty in interpreting the setae on segments III to V. However, seta 3 is represented only by its socket on these segments. Seta 3 is entirely absent from segment VI, but otherwise the setae of this segment are similar to those of III through V.

Segment VII presents some difficulties. Seta 3 is entirely absent as on segment VI, and the larger postero-lateral seta, which is usually a tuft in non-anopheline pupae, is considered homologous to seta A of other segments. The other setae fall fairly easily into line. In some species of *Aedes*, seta 1 may approach the size and importance of A; and in *Armigeres* seta B is so reduced in size that it is difficult to assign with certainty.

Segment VIII has only three setae dorsally. These are difficult to homologize with those of the other segments, and hence are generally designated simply as A, the larger postero-lateral tuft; A', the smaller seta mesad of A; and 5, apparently the same seta as in the other segments.

Segments IX and X have one pair of small setae each in only a few genera. Seta v on segment IX is present in *Uranotaenia*, *Aedomyia*, and *Culex* only, while seta w on segment X is present only in *Megarhinus*.



Using Macfie's work as a basis, in Table 1 I have attempted to homologize as far as possible the various modifications of the system of classifying the dorsal abdominal setae which have been presented in the literature, and the slightly modified system used in this study.

TABLE 1  
HOMOLOGIES OF DORSAL ABDOMINAL SETAE  
OF MOSQUITO PUPAE

Macfie (1920) Culic.	Senevet (1930) Anoph.	Baisas (1936) Anoph.	(1938) Culic.	Rozeboom & Knight (1946)	Present Study
Segment I:					
(C'') *	H	H	H	9	H
(C')	K	K	K	6	K
(B')	L	L	L	5	L
(B)	M	M	M	4	M
(A'')	S	T	S	2	S
(A')	T	S	T	3	T
(A)	U	U	U	1	U
(C)	1	t	----	10	float- hair
Segment II:					
A	----	A	A	1	A
C'	III	3	B	10	B
C	C	C	C	9	C
C''	IV	4	3	5	C'
A'	I	1	----	3	1
A''	I'	1	1	2	2
B	II	2	2	4	3
B'	II'	2	4	6	4
D	V	5	5	7	5
Segment III:					
A	9	A	A	1	A
C'	B	B	B	5	B
C	C	C	C	10	C
C''	C'	C'	C'	9	C'
A'	I	1	1	2	1
B	II	2	2	4	2
----	III	----	3	3	3
B'	IV	4	4	6	4
D	V	5	5	7	5
Segments IV-VII:					
A	9	A	A	1	A
B	B	B	B	8	B
C	C	C	C	10	C
C''	C'	C'	C'	9	C'
A'	I	1	1	2	1
B'	II	2	2	4	2
----	III	----	3	3	3†
C'	IV	4	4	6	4
D	V	5	5	7	5
Segment VIII:					
A	6	A	A	1	A
P	7	A'	A'	8	A'
D	8	5	5	7	5

\* These setae are not actually designated by Macfie, but their possible homologies to those of the following segments are so indicated.  
† Seta 3 not present on segments VI and VII.

No attempt has been made to utilize the ventral abdominal setae in the descriptions, hence no comment concerning them is called for here.

SYSTEMATIC TREATMENT

All of the species recorded in this paper belong to the subfamily Culicinae, as no species of the subfamily Chaoborinae have been recorded from New Guinea. However, it is possible that the latter have been overlooked and a key separating the pupae of the two subfamilies is included. The subfamily key was taken with slight change from Edwards (1932: 8). The key to genera and subgenera of Culicinae is largely original, but based somewhat on a key to Ethiopian pupae in Edwards (1941); all other keys are original.

Key to Subfamilies

- 1. Paddles fused basally, not movable; spiracle beyond middle of respiratory trumpet .....  
.....Genus *Corethrella* of **Chaoborinae**
- Paddles free, movable ..... 2
- 2. Respiratory trumpet either almost closed apically or with the spiracle near its middle .....**Chaoborinae**
- Trumpet open at tip, internal spiracle at base .....**Culicinae**

Key to Genera and Subgenera of Culicinae

- 1. Paddles relatively small, without setae; seta A-VIII as long as or longer than the paddles ..... 2
- Paddles relatively large, with or without setae; seta A-VIII never as long as the paddles ..... 5
- 2. Trumpets with inner wall well separated from outer wall; seta K-I long, other setae on segment I small.....  
.....**Harpagomyia** p. 27.
- Trumpets with inner and outer wall in contact; K, S, and T of segment I all long ..... 3
- 3. Seta B-VII very long, extending well beyond posterior margin of segment VIII, usually beyond apex of paddles .....**Tripteroides** (**Tripteroides**) p. 25.
- Seta B-VII at most extending to about middle of segment VIII, usually much shorter ..... 4

4. Seta 2 the most conspicuous seta on segment II, usually about twice as long as seta B; upper postocular seta (1) of cephalothorax two- or three-branched ..... *Tripteroides (Mimeteomyia)* p. 23.  
Seta 2 smaller, or equal to, B which is the most conspicuous seta on segment II; upper postocular seta (1) of cephalothorax simple, not branched.....  
..... *Tripteroides (Rachisoura)* p. 23.
5. Anal segment (X) with a pair of setae; paddles broad, lateral face longer than medial face, with hair-like fringe and without terminal setae.....  
..... *Megarhinus* p. 23.  
Anal segment (X) without setae; paddles with lateral and medial faces approximately equal in length, if fringed with hairs then they also have terminal setae ..... 6
6. Setae A-III-VI stout, peg-like (apex pointed or rounded), always on posterior margin at or near to postero-lateral corner of segments..... 7  
Setae A-III-VI small, simple spines on lateral margin above postero-lateral corners of the segments..... 8
7. Float-hair on segment I dendritic; paddles with both terminal and accessory setae..... *Anopheles* p. 11.  
..... *Bironella* p. 21.  
Float-hair on segment I with eight to ten short simple branches; paddles with only the simple terminal seta.....  
..... *Aedomyia* p. 38.
8. Trumpets divided to base into two movable leaflets, no meatus.....  
..... *Hodgesia* p. 28.  
Trumpets undivided, with well-marked meatus ..... 9
9. Trumpets long, with basal half or more tracheoid ..... 10  
Trumpets short, or only moderately long; tracheoid area when present usually occupying much less than half the meatus ..... 14
10. Trumpet with tip highly modified for piercing plants; paddles narrowed and notched apically, without setae; no float-hair on segment I..... 11  
Trumpet not modified for piercing; segment I with normal float-hair or at least a seta in its place..... 12
11. All abdominal setae very small and weak ..... *Mansonia (Coquillettidia)* p. 37.  
Setae B and C forming long stout bristles ..... *Mansonia (Mansonioides)* p. 37.
12. Paddles very narrow, over four times as long as wide; trumpets very long, tracheoid for more than three-fourths of their length; float-hair reduced to a single stout seta .....  
..... *Ficalbia (Etorleptiomyia)* p. 35.  
Paddles not more than twice as long as broad; trumpets not so extremely long, and tracheoid for not more than two-thirds of their length; float-hair not a single seta..... 13
13. Dorsal seta placed far behind trumpets; paddles fringed or strongly denticulate and often with light or dark spots.....  
..... *Ficalbia (Mimomyia)* p. 35.  
Dorsal setae placed between or scarcely behind the trumpets; paddles with margins smooth or finely serrate but never fringed .....  
..... *Uranotaenia (Uranotaenia)* p. 29.
14. Paddles without terminal setae.....  
..... *Culex (Acalyntrum)* p. 76.  
Paddles with at least the terminal seta (x) ..... 15
15. Paddles nearly always with accessory seta placed beside the terminal seta; segment IX nearly always with seta v present ..... 16  
Paddles with terminal seta but without accessory seta; segment IX without seta v ..... 21
16. Paddles with serrate margins; seta v at least equal to the length of segment IX .....  
..... *Uranotaenia (Pseudoficalbia)* p. 29.  
Paddles with smooth margins; seta v minute, never more than one-fourth the length of segment IX..... 17
17. Seta A far anterior to the postero-lateral corners on segments III-VI; paddles slightly notched at apex; large species ..... *Culex (Lutzia)* p. 68.  
Seta A near to the postero-lateral corners on segments III-VI; paddles not notched at apex; size variable..... 18
18. Seta K on segment I usually simple; all cephalothoracic setae small and inconspicuous .....  
..... *Culex (Mochthogenes)* p. 69.



- Seta K on segment I usually two-branched; at least some of cephalothoracic setae conspicuous.....19
19. Seta C-II always more than fifteen-branched....*Culex (Culiciomyia)* p. 72.  
Seta C-II never more than fourteen-branched, usually much less.....20
20. Trumpet long, length more than nine times the greatest diameter of meatus; pinna short, less than one-fifth of the total length of trumpet.....*Culex (Lophoceraomyia)* p. 69.  
Trumpet short, length never more than five times the greatest diameter of meatus; pinna long, more than one-fourth of total length of trumpet.....*Culex (Culex)* p. 78.
21. Paddles elongate, length more than twice greatest width .....*Aedes (Macleaya)* p. 54.  
Paddles more or less rounded, length never more than one and one-half times the greatest width.....22
22. Dorsal seta (8) of cephalothorax set well behind the bases of the trumpets.....23  
Dorsal seta (8) of cephalothorax set between or only slightly behind the bases of the trumpets.....24
23. Seta S on segment I a small tuft; seta C'-II absent.....*Armigeres* p. 64.  
Seta S on segment I long, simple or two-branched, but never a tuft; seta C'-II present.....*Aedes (Stegomyia)* p. 55.
24. Setae H and K wide apart, K as near to L as to H.....*Aedes (Banksinella)* p. 61.  
Setae H and K near together and well apart from L and M.....25
25. Seta B very long, exceeding posterior margin of following segment on at least segments IV and V.....26  
Seta B smaller, not reaching posterior margin on any segments.....29
26. Seta C-II separated from B-II by nearly the length of segment II; trumpets long with fairly well-developed tracheoid area, though the rings are not complete.....*Aedes (Mucidus)* p. 40.  
Seta C-II usually rather close to B-II, separated by not more than half the length of segment II; trumpets short, tracheoid area obsolete, or at most represented by one or two incomplete rings .....27
27. Seta C-II a medium-length, ten- to fifteen-branched, often dendritic tuft.....*Aedes (Aedes)* p. 62.  
Seta C-II of various lengths, not over six-branched, never dendritic.....28
28. Paddles with smooth or serrate margins, never with a fringe of hairs.....*Aedes (Finlaya)* p. 42.  
Paddles with a marginal fringe of long fine hairs.....*Aedes (Skusea)* p. 54.
29. Setae B and C simple on most of the segments .....*Aedes (Leptosomatomyia)* p. 63.  
Setae B and C branched or forked on most of the segments.....*Aedes (Aedimorphus)* p. 60.
- Genus *ANOPHELES* Meigen
- DIAGNOSIS: Trumpets short and widely open. Abdomen with seta A spine-like, stout, and placed at or close to the postero-lateral corners of segments III to VI. Paddles with a terminal seta at end of midrib and a smaller accessory seta subapically.
- Key to Species of *Anopheles*
1. Setae B and C on IV-VII multi-branched with central branch nearly twice as long and stout as other branches; terminal seta of paddles short, straight, and with two to four side branches (Fig. 5) .....*A. (A.) barbirostris barbirostris*  
Setae B and C on IV-VII never multi-branched, at most four- to five-branched and all branches subequal; terminal seta of paddles longer, straight or hooked..... 2
  2. Paddle with a series of strong denticles on the lateral margin..... 3  
Paddle without denticles, fringe consisting of fine hairs only..... 5
  3. Seta A-V approximately equal to A-III in length; terminal seta of paddle straight.....*A. (M.) lungae*  
Seta A-V approximately two or three times the length of A-III; terminal seta of paddle hooked..... 4
  4. Seta A-VI no more than a third longer than seta A-V; terminal seta of paddle weak (Fig. 6).....*A. (M.) karwari*  
Seta A-VI more than twice as long as seta A-V; terminal seta of paddle strong (Fig. 7) .....*A. (M.) subpictus subpictus*

5. Seta B-II with thirteen or more branches; dorsal seta (8) of cephalothorax over 105 microns long..... 6
- Seta B-II with less than thirteen branches; dorsal seta (8) less than 105 microns long..... 7
6. Seta A-VII smooth, slender, averaging 153 microns in length; seta B-II branched from near base (Fig. 8).....  
.....A. (M.) *punctulatus*  
Seta A-VII stout, with a distinct rugose constriction near base, averaging about 82 microns long; seta B-II with main branching arising at basal third from a stout stalk.....A. (M.) *clowi*
7. Seta A-IV less than one-half the length of seta A-V (Fig. 9)....A. (M.) *farauti*  
Seta A-IV one-half or more the length of seta A-V (Fig. 10).....  
.....A. (M.) *koliensis*

*Anopheles (Anopheles) barbirostris barbirostris* Van der Wulp 1884

Fig. 5

Pupa fully described by Senevet (1932: 209) from Karwar, India, and by Crawford (1938: 39) from near Singapore, Malaya. The figure and the following description have been taken largely from Crawford's paper.

DIAGNOSIS.—Separable from all other known anophelines of New Guinea in having setae B and C on segments IV to VII multi-branched with the central branch nearly twice as long and stout as the other branches of the tuft. Terminal seta of paddles short, straight, and with two to four side branches.

CEPHALOTHORAX.—*Postocular*: 1 fairly long, two- to four-branched; 2 long, two- to five-branched; 3 long, two- to five-branched.

*Anterothoracic*: 4 medium, two- to three-branched; 5 long, two-branched or occasionally three-branched; 6 longer, two-branched or simple; 7 long, two-branched or simple.

*Dorsal*: 8 medium, simple, stout.

*Supra-alar*: 9 long, simple or two-branched.

*Metanotum*: 10 medium, two- to four-branched; 11 fairly long, two- to three-branched or occasionally simple; 12 long, two- to three-branched or simple.

*Trumpet*: Dark brown, expanded, somewhat boat-like.

ABDOMEN.—*Segment I*: H fairly short, two- to three-branched or simple; K medium length, two- to four-branched; L fairly short, four- to six-branched; M long, two- to three-branched from near base; S fairly long, two- to five-branched from proximal fourth; T long, about one and one-half times S, simple or occasionally two-branched; U short, simple or two-forked.  
*Segment II*: A minute; B medium, simple or occasionally two-branched; C long, four- to ten-branched from near base or higher; C' fairly long, five- to eleven-branched; 1 long, simple;

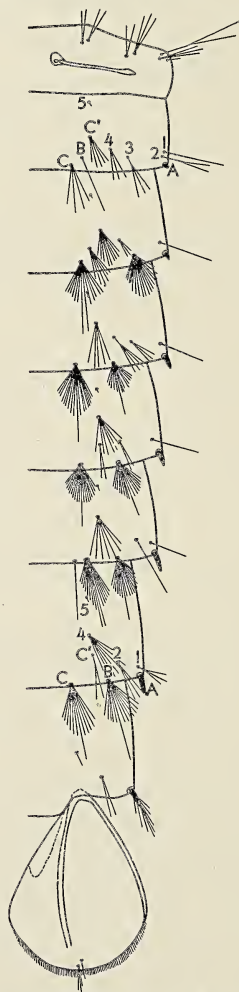


FIG. 5. *Anopheles barbirostris barbirostris*: dorsal aspect of right half of abdomen of male (after Crawford, 1938).



2 slightly shorter, simple or two- to four-branched; 3 medium, two- to three-branched; 4 fairly short, two- to six-branched, commonly three- to four-branched.

*Segment III:* A short peg about twice the length of A-II; B fifteen- to forty-branched tuft; C a tuft of twelve to thirty-eight branches with long central branch; C' long, three- to seven-branched; 1 long, simple; 2 fairly short, two- to four-branched or rarely simple; 3 represented only by its socket; 4 long, five- to twelve-branched.

*Segment IV:* A short spine, yellow, beak-like, little or no curve, pointed; B twenty-two- to fifty-branched tuft with long central branch; C eighteen- to fifty-branched tuft with long central branch; 1 long, simple; 2 short, two- to four-branched; 3 represented only by its socket; 4 medium, four- to seven-branched; C' medium, two- to five-branched, commonly three-branched.

*Segment V:* A similar to and slightly longer than A-IV; B twenty- to fifty-branched tuft with one or two long central branches; C similar to B, with thirty-three to fifty branches; C' fairly long, two-branched or simple; 1 long, simple; 2 medium length, two- to four-branched; 3 represented only by its socket; 4 fairly long, four- to eight-branched.

*Segment VI:* A similar to and slightly longer than A-V; B twenty- to forty-branched strong tuft with a long central branch; C similar to and same length as B with twenty-nine to fifty branches; C' long, simple or two-forked near base or higher; 1 long, simple; 2 long, simple or two-branched; 3 absent; 4 long, three- to seven-branched.

*Segment VII:* A similar to A-VI, about one-tenth of the segment; B fairly strong seventeen- to forty-branched tuft with long central branch; C medium, strong seventeen- to fifty-branched tuft with long central branch; C' long, two- to three-forked from proximal one-fourth; 1 fairly short, two- to five-branched; 2 fairly long, simple or two-branched; 4 slightly shorter, five- to eight-forked from near base or higher.

*Segment VIII:* A medium length, stalk long with ten to fifteen inconspicuous branches; A'

slightly longer than A, two- to three-forked from proximal one-third or simple; 5 short, two- to three-branched or simple.

*Paddles:* Broadly ovoid; lateral margin with small teeth proximally, replaced by short hairs distally; medial margin with similar short hairs almost to level of genital pouches; base of paddle pigmented; terminal seta short, with one to four fine side branches on its distal half, or bifid; accessory seta almost as long as terminal seta, two-branched or simple.

**Anopheles (Myzomyia) lungae** Belkin and Schlosser 1944

This pupa has not been fully described or figured, but Belkin, Knight, and Rozeboom (1945: 251) gave a diagnostic description from which the following notes have been taken.

**DIAGNOSIS.**—Paddle with a series of strong denticles on the lateral margin; seta A-V approximately equal to A-III in length; terminal seta of paddle straight.

**ABDOMEN.**—*Segment I:* H averages six-branched, range from five to seven; K usually simple, occasionally two-branched.

*Segment II:* C averages seven-branched, range from five to ten; C' averages three-branched, range from one to four.

*Segment III:* A short, simple; C averages four-branched, range from three to six; C' averages two-branched, range from simple to two.

*Segment IV:* A short, about equal to A-III; C averages three-branched, range from two to five; 1 averages two-branched, range from simple to three.

*Segment V:* A short, about equal to A-III; C averages three-branched, range from two to four; 1 averages two-branched, range from simple to three.

*Segment VI:* A much longer, at least three times A-V, extremely slender and pale, frequently branched or apically frayed; C averages two-branched, range from simple to four; 4 averages four-branched, range from three to five.

*Segment VII:* A slightly longer, similar, with



one or more branches in over 80 per cent of the specimens examined; B averages four-branched, range from three to six; 4 averages four-branched, range from two to six.

*Segment VIII:* A a little longer, usually simple, occasionally two-branched; A' averages two-branched, range from two to three.

**Anopheles (Myzomyia) karwari** (James) 1903

Fig. 6

This pupa was fully described and figured by Senevet (1932:223) from Cochin-China, French Indo-China; by Baisas (1936: 74, 212) from the Philippine Islands; and by Crawford (1938: 89) from near Singapore, Malaya. The figure and the following description have been taken largely from Crawford's paper.

**DIAGNOSIS.**—Together with *A. subpictus* *subpictus* the pupa of this species can be distinguished from all other known anophelines of New Guinea by the following characters: seta A-V approximately two or three times as long as A-III; terminal paddle seta long and hooked, the lateral margin with denticles proximal to the fringe of hairs. Seta A-VI is no more than a third longer than A-V in *karwari*, but A-VI is more than twice as long as A-V in *subpictus*.

**CEPHALOTHORAX.**—*Postocular:* 1 medium, two- to three-branched; 2 medium, two- to four-forked from proximal one-third; 3 medium, two- to four-branched.

*Anterothoracic:* 4 medium, three- to six-branched; 5 medium, two- to six-branched; 6 fairly long, two- to four-branched; 7 long, two- to three-forked from near base or simple.

*Dorsal:* 8 fairly short, simple.

*Supra-alar:* 9 medium, two- or three-branched.

*Metanotum:* 10 fairly long, simple or occasionally two-forked; 11 fairly short, two- to four-forked at proximal fourth; 12 long, two- to five-branched near middle.

*Trumpet:* Tubular.

**ABDOMEN.**—*Segment I:* H short, simple; K medium, four- to six-branched; L fairly short,

two- to six-branched; M fairly long, three- to four-branched; S fairly long, two- to six-branched; T long, two- to three-branched; U very short, simple.

*Segment II:* A minute, colorless; B medium, simple or occasionally two-forked, stout; C fairly long, six- to twelve-forked, usually eight- to nine-forked from near base and higher; C' short, two- to three-branched; 1 fairly long, two- to three-branched, rarely simple; 2 about same length, three- to seven-branched; 3 short, two- to three-branched; 4 long, simple or two-branched.

*Segment III:* A minute, colorless; B fairly long, three- to six-branched; C long, almost equal to

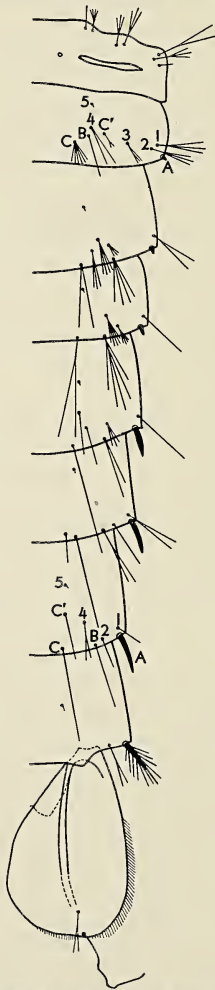


FIG. 6. *Anopheles karwari*: dorsal aspect of right half of abdomen of male (after Crawford, 1938).

tergite, three- to six-branched; 1 fairly long, two- to four-forked from proximal third; 2 short, three- to six-branched; 3 represented only by its socket; 4 fairly long, two- to five-forked from near base or higher; C' fairly long, two- to three-branched or simple.

*Segment IV:* A minute; B long, three- to five-branched; C long, about length of tergite, simple or two- to three-branched; C' medium, three- to four-branched; 1 long, simple or occasionally two- to three-forked from middle; 2 short, two- to seven-forked from proximal one-half; 3 represented only by its socket; 4 fairly long, simple or two- to three-branched.

*Segment V:* A long, curved, tapered to a fine point, about one-third length of tergite; B long, simple or bifurcated; C long, simple or occasionally with one side branch; C' fairly long, two- to three-branched or occasionally simple; 1 long, simple or two-branched; 2 medium, two- to four-branched; 3 represented only by its socket; 4 fairly long, simple or two-branched.

*Segment VI:* A similar to A-V but a little longer; B long, commonly with two unequal branches from proximal one-fourth, or simple with one to two fine side branches, about two-thirds length of tergite; C long, longer than tergite, generally simple, occasionally with two unequal branches about middle, or with one side branch; C' medium, one-third to one-half of C, two-branched or occasionally simple or three-branched; 1 long, two-forked from middle one-third, occasionally three-forked or simple; 2 slightly shorter, simple or two-branched, occasionally three-branched; 3 absent; 4 fairly long, simple or two-branched.

*Segment VII:* A long, curved, tapered to a fine point, a little less than half of tergite in length; B long, simple or with one to two small side branches; C long, slightly longer than tergite, generally simple but may be bifurcate or have a fine side branch; C' short, two- to three-branched, occasionally simple; 1 short, two- to three-branched or simple; 2 slightly longer, simple or two-forked from middle one-third; 4 medium, two-branched or simple.

*Segment VIII:* A long, stalk about one-third total length, with seven to fifteen stout branches, three to five being terminal; A' fairly long, two- to three-branched, occasionally simple; 5 minute, simple.

*Paddle:* Base of lateral margin with small pointed teeth, distally their apices taper into hairs which form a fringe extending a short distance around the apex to the medial margin; midrib stout, not reaching accessory seta; terminal seta long, hook-like; accessory seta fairly short, two- to three-branched, well removed from apex of paddle.

**Anopheles (Myzomyia) subpictus subpictus**  
Grassi 1899

Fig. 7

This pupa was fully described by Senevet (1931: 38) from Kasauli, India. The figure and the description which follow have been taken from Senevet's paper.

**DIAGNOSIS.**—Together with *A. karwari* the pupa of this species is set apart from all other anophelines known from New Guinea by the denticulated lateral margin of the paddle, the long seta A-IV, and the long hooked terminal seta on the paddle. From *karwari* it can be distinguished by the length of seta A-VI which is more than twice as long as A-V in *subpictus* while it is no more than a third longer than A-V in *karwari*.

**CEPHALOTHORAX.**—*Metanotum:* 10 long, strong, bifurcate; 11 medium, very fine, three-branched; 12 long, three-forked.

**ABDOMEN.**—*Segment I:* H medium, simple; K medium, four-branched; L short, five- to six-branched; M fairly long, three-branched; S medium, three- to four-branched; T and U long, simple.

*Segment II:* A minute; B fairly long, simple; C with central short stem bearing three to four branches on each side, about one-half the length of the segment; C' medium, three- to four-branched near apex; 1 fairly long, simple; 2 medium, three- or four-branched; 3 medium, three- to four-branched; 4 fairly long, five- to six-branched; 5 short, simple.



*Segment III*: A a little longer, rounded; B fine, six- to seven-branched, one-half the length of the segment; C one-third length of segment, four- to six-branched; C' fairly long, strong; 1 fairly long, bifurcate; 2 medium, four- to five-branched; 3 represented only by its socket; 4 fairly long, five- to six-branched.

*Segment IV*: A a little longer, apex rounded; B two-thirds length of segment, four- to five-branched; C about as long as the segment, two- to three-branched; C' medium, four- to five-branched; 1 long, simple; 2 medium, four- to five-branched; 3 represented only by its socket; 4 fairly long, four- to six-branched.

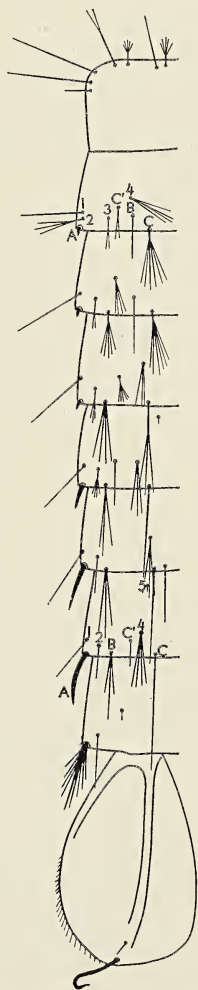


FIG. 7. *Anopheles subpictus subpictus*: dorsal aspect of left half of abdomen of male (after Senevet, 1931).

*Segment V*: A longer, less than one-third of segment, apex not very pointed; B about two-thirds length of segment, two- to three-branched; C simple, strong, slightly longer than segment; C' fairly long, simple; 1 long, simple; 2 medium, three- to four-branched; 3 represented only by its socket; 4 fairly long, three- to four-branched.

*Segment VI*: A longer, about one-half the length of segment; B about same as B-V; C simple, strong, longer than segment; C' long, simple, half as long as C; 1 fairly long, bifurcate; 2 fairly long, simple; 3 absent; 4 long, three- to four-branched.

*Segment VII*: A slightly longer than one-half of segment VIII; B about same as B-VI; C simple, strong, slightly longer than segment; 1 medium, simple; 2 fairly long, simple; 4 long, five-branched.

*Segment VIII*: A with fairly long central stalk, having two or three fairly strong branches on each side, and terminating in two long and strong branches, total length about one-fourth of the paddle; A' slightly longer than A, simple.

*Paddle*: Little elongated; external margin bare on its anterior one-fourth, presenting on the following one-fourth a few small triangular, short, pointed spines in two to four rows; these spines are elongated on the next one-fourth, and the margin becomes almost serrated; these spines are curved to the rear on the posterior one-fourth and abruptly replaced by hairs which are much longer, but which decrease rapidly and do not reach the terminal seta; terminal seta long, simple and hooked; accessory seta small, simple, not reaching apex of paddle.

*Anopheles (Myzomyia) punctulatus* Dönitz 1901

Fig. 8

The pupa of this species was partially described and figured by Belkin, Knight, and Rozeboom (1945: 253) from the Solomon Islands, and by Rozeboom and Knight (1946: 108), who also compared it in many details with *A. farauti* and *A. koliensis* from the Solomon Islands and New Guinea.

**DIAGNOSIS.**—Very similar to *A. clowi*, together with which it can be separated from all other species of the *punctulatus* complex in having seta B-II with thirteen or more branches and the dorsal seta (8) of the cephalothorax over 105 microns long. The differences between *punctulatus* and *clowi* as reported by Rozeboom and Knight seem to be very minor and may not hold when more specimens of *clowi* have been examined.

**CEPHALOTHORAX.**—Postocular, anterothoracic and supra-alar setae similar to those in *A. farauti*.

**Dorsal:** 8 long, usually more than 105 microns in length.

**Metanotum:** 10 long, simple; 11 medium, two-forked; 12 medium, two-forked.

**Trumpet:** Similar to that of *A. farauti* in proportions, but paler and not offering much contrast to the general color of the cephalothorax.

**ABDOMEN.**—**Segment I:** H medium, simple; K medium, three- to eight-forked; L small, two- to four-forked; M long, three-forked; S very long, three- to four-forked; T long, six-forked; U small, simple.

**Segment II:** A small, stout peg; B long, simple; C long, averages eighteen-branched, usually more than thirteen but ranging from seven to thirty-eight; C' small, simple or three-forked; 1 small, four- or five-forked; 2 long, simple to three-forked; 3 medium, three- or four-forked; 4 long, five- to eight-forked; 5 minute, simple on this and all following segments.

**Segment III:** A small, slightly longer than A-II; B medium, six- to nine-branched; C long, averages ten-forked, range from four- to sixteen-forked; C' medium, simple to three-forked; 1 medium, two-forked near apex, range from simple to five-forked; 2 small, simple or five-forked; 3 represented only by its socket; 4 medium, four- to seven-forked.

**Segment IV:** A small, roughly equal to A-III; B long, four- or five-branched; C long, four- to eight-forked; C' medium, four- to six-forked; 1 medium, simple or two-forked; 2 small, three- or four-forked near apex; 3 represented only by its socket; 4 medium, five- to six-forked.

**Segment V:** A long, approximately four or five times as long as A-IV; B long, three- to five-forked; C long, two- to four-forked; C' medium, simple; 1 medium, simple to three-forked; 2 small, simple to three-forked; 3 represented only by its socket; 4 medium, four-forked.

**Segment VI:** A longer than A-V; B long, four-branched; C long, simple or three-forked; C' medium, simple; 1 medium, simple or two-forked; 2 small, simple; 3 absent; 4 medium, three- to five-forked.

**Segment VII:** A longer than A-VI, nearly twice as long as A-V; B long, two- to five-forked; C long, simple; C' small, three-forked near apex; 1 small, simple; 2 small, simple; 4 medium, three- to five-forked.

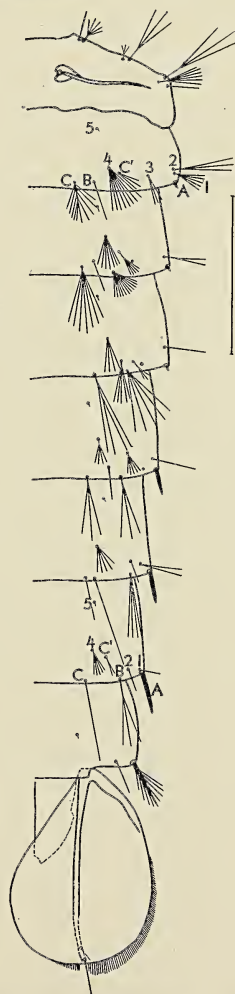


FIG. 8. *Anopheles punctulatus*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.



*Segment VIII*: A about equal to A-VII, with ten to twelve small side branches; A' medium, simple to three-forked.

*Paddle*: Roundly oval in shape, about one-fourth longer than wide; margin without denticles but produced into a fringe of fine hairs around the apex to a point mesad of the terminal seta; midrib strong, dividing the paddle unequally, the lateral face wider than the medial face; terminal seta medium, usually straight; accessory seta small, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of five males and two females from Hilimoi, Milne Bay, Papua.

**Anopheles (Myzomyia) farauti** Laveran 1902

Fig. 9

The pupa has been rather completely described and figured by several authors. Buxton and Hopkins (1927: 67) gave a brief description and figures of the terminal abdominal segments and paddles as *A. punctulatus* from the New Hebrides; Senevet (1930: 337) gave a complete detailed description and figures of the abdomen, paddles, and trumpet as *A. punctulatus* from the New Hebrides; Belkin, Knight, and Rozeboom (1945: 258) gave a complete description of specimens from the Solomon Islands; and Rozeboom and Knight (1946: 108) compared *farauti* with *punctulatus* and *koliensis* from the Solomon Islands and New Guinea in many details and gave a complete set of figures of the abdomen and cephalothorax.

**DIAGNOSIS**.—Similar to *A. koliensis* with which it differs from others of the *punctulatus* complex in having seta B-II with less than thirteen branches and dorsal seta (8) of cephalothorax less than 105 microns long. It differs from *koliensis* in having seta A-IV less than one-half the length of A-V.

**CEPHALOTHORAX**. — *Postocular*: 1 small, three- to four-branched; 2 medium, four-forked; 3 small, three forked.

*Anterotheracic*: 4 small, four- to six-forked; 5 small, three- to five-forked; 6 medium, two-forked; 7 medium, two-forked.

*Dorsal*: 8 medium, simple or two-forked (less than 105 microns in length according to Belkin, et al.).

*Supra-alar*: 9 medium, two- to three-forked.

*Metanotum*: 10 medium, simple or two-forked near apex; 11 medium, three- to five-forked near middle; 12 long, two- to four-forked near middle.

*Trumpet*: Orange-brown, contrasting noticeably with the color of the cephalothorax, pigmented area extending basally from the apex at least to the base of the pinna.

**ABDOMEN**.—*Segment I*: H medium, simple or rarely two-forked; K medium, five-forked near basal one-fourth, occasionally simple or four-forked; L small, three-forked near middle; M long, three-forked near middle, rarely four-forked; S very long, three-forked near basal one-fourth; T long, five- to six-forked near basal third; U small, two-forked near apex or simple.

*Segment II*: A very small, stout peg; B long, simple; C long, three- to sixteen-forked, usually less than thirteen-forked; C' medium, three- to five-forked; 1 long, four-forked near basal third; 2 very long, simple or occasionally two- or three-branched; 3 medium, four- or three-forked; 4 medium, five- to seven-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, about twice length of A-II; B long, six-forked; C long, five- to eleven-branched; C' long, simple; 1 very long, simple or occasionally three-forked; 2 small, simple or rarely three-forked; 3 represented only by its socket; 4 medium, four- or five-forked.

*Segment IV*: A about twice the length of A-III, averaging 29 microns in length according to Rozeboom and Knight; B long, six-forked; C long, usually six-forked, range from three- to eight-forked; C' small, five-forked; 1 long, simple; 2 small, simple; 3 represented only by its socket; 4 medium, four- to five-forked.

*Segment V*: A longer, more than twice the length of A-V; B medium, from four- to five-forked; C long, usually three-forked, range from

two- to six-forked; C' medium, three-forked from near middle; 1 long, simple or rarely two-forked; 2 small, simple or two-forked; 3 represented only by its socket; 4 medium, four-forked.

*Segment VI*: A longer than A-V; slightly plumose or frayed; B long, three- or four-forked; C long, two- to four-forked; C' medium, simple or rarely three-forked at apex; 1 medium, simple; 2 small, simple; 3 absent; 4 medium, three- to six-forked.

*Segment VII*: A about equal to and similar to A-VI; B long, three-forked, range from two- to four-forked; C long, simple; C' small, simple or rarely two-forked at apex; 1 small, simple or

rarely three-forked near middle; 2 small, simple; 3 absent; 4 small, three- to six-forked.

*Segment VIII*: A about equal in length to A-VII, with eight to eleven fine side branches; A' small, two-forked, occasionally simple or three-forked.

*Paddle*: Roundly oval in shape, about one-fourth longer than wide; margin without denticles but produced into a fringe of fine hairs around the apex to a point a little mesad of the terminal seta; midrib strong, dividing the paddle unequally, lateral face wider than medial face; terminal seta long, simple, usually hooked; accessory seta small, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of four males and six females from Gamadodo, WagaWaga, Hilimoi, and KanaKope, Milne Bay, Papua, and Amsterdam Island, Dutch New Guinea.

*Anopheles (Myzomyia) clowi* Rozeboom and Knight 1946

The pupa was described from the single type specimen by Rozeboom and Knight (1946: 114) from Hollandia, Dutch New Guinea. This constitutes the lone record of this species. The following descriptive notes were taken from this paper; no figures were given.

**DIAGNOSIS**.—Very similar to *A. punctulatus* from which it can be distinguished by the structure of seta A-VII, this seta having a distinct rugose constriction near its base and averaging about 82 microns in length; and by seta B-II with its main branching arising at the basal one-third from a stout stalk.

**CEPHALOTHORAX**.—*Dorsal*: 8 long, 153 to 167 microns.

*Metanotum*: 10 longer, 177 to 180 microns.

*Trumpet*: Paley pigmented over entire length, offering only slight contrast to rest of cephalothorax; ratio of depth of basal notch to length of trumpet approximately 1:1.4.

**ABDOMEN**.—*Segment I*: H two- to four-branched; K simple.

*Segment II*: C distinctive in possessing a dark, stout, basal stalk which is approximately one-third the total length of the seta, seventeen- to eighteen-branched; C' long, stout, simple.

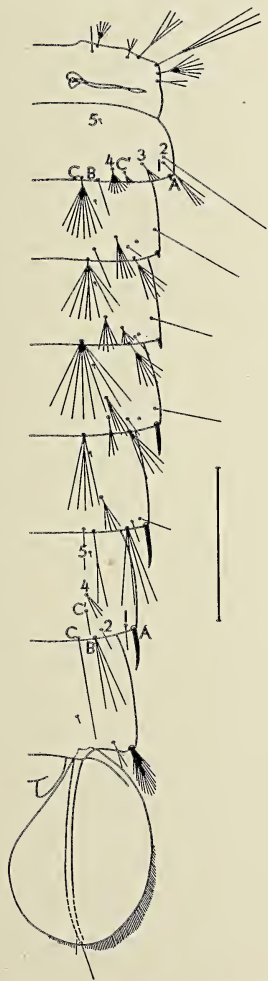


FIG. 9. *Anopheles farauti*: dorsal aspect of right half of abdomen of female from Amsterdam Island, Dutch New Guinea.



*Segment III:* A short, 14 to 17 microns; B eleven-branched; C nine-branched; C' two-branched.

*Segment IV:* A darkly pigmented, stout, smoothly and acutely tapered, about twice the length of A-III; B four-branched; C three- to four-branched; C' external to B in position; 1 simple.

*Segment V:* A similar to and about twice the length of A-IV; B two- to four-branched; C two-branched; 1 simple.

*Segment VI:* A similar to and about the same length as A-V; B three-branched; C simple to three-branched; 4 four-branched.

*Segment VII:* A similar to and about same length as A-VI; B three-branched; C long, simple or two-branched; C' four-branched.

*Segment VIII:* A' three-branched.

*Paddle:* Midrib with external margin distinct to posterior two-thirds; buttress well developed, external margin of paddle distinct to posterior half and possessing minute, clear spinules that increase in size posteriorly to beginning of fringe; fringe of fine pale hairs extending from center of external margin to the beginning of anterior curve internal to terminal seta, longest just external to this seta. Terminal seta straight, rather stout, darkly pigmented.

**Anopheles (Myzomyia) annulipes** Walker 1856

This pupa is undescribed except for a brief note of doubtful value given by Cooling (1924: 21) which reads, "The pupa is distinguished by the broad triangular breathing trumpets; they are pale and rather mottled."

**Anopheles (Myzomyia) koliensis** Owen 1945

Fig. 10

This pupa has not been fully described or figured previously, but Belkin, Knight, and Rozeboom (1945: 261) gave a diagnostic description, and Rozeboom and Knight (1946: 108-111) included a few notes in their work on the *punctulatus* complex.

**DIAGNOSIS.**—Very similar to *A. farauti* but separable on the basis of the relative lengths of setae A-IV and A-V. Rozeboom and Knight

(1946: 110) examined a large series and found that in *koliensis* seta A-IV was more than one-half the length of A-V in 97.7 per cent of the specimens, while in *farauti* seta A-IV was less than one-half the length of A-V in 89.4 per cent of the specimens.

**CEPHALOTHORAX.** — *Postocular:* 1 small, usually simple; 2 small, two-forked near middle; 3 small, three-forked near middle.

*Anterothoracic:* 4 small, three- to six-forked; 5 medium, three- or four-forked near middle; 6 medium, simple or two-forked near middle; 7 long, two-forked near basal one-third.

*Dorsal:* 8 small, two-forked near base, less than 105 microns in length, averages 69 microns.

*Supra-alar:* 9 small, four-forked near middle.

*Metanotum:* 10 medium, simple; 11 medium, three- or four-forked near middle; 12 medium, three- or four-forked near middle.

*Trumpet:* Similar to that of *A. farauti*.

**ABDOMEN.**—*Segment I:* H medium, always simple; K medium, averages five-branched, range from three to six; L small, three-forked near middle; M long, three- or four-forked near basal one-third; S long, three- or four-forked near basal one-third; T medium, three-branched; U small, simple.

*Segment II:* A very small, transparent; B long, always simple; C usually six-branched, range from two to eleven; C' small, four-branched; 1 long, simple; 2 medium, four-branched; 3 medium, four-forked near basal one-third; 4 medium, six-branched; 5 small, simple, on this and all following segments.

*Segment III:* A small, transparent, about twice the length of A-II; B medium, six-branched; C medium, averages ten-branched, range from seven to thirteen; C' medium, usually simple, occasionally two-branched; 1 long, equal to 1-II, usually simple, range from one- to three-branched; 2 small, three-forked near middle; 3 represented by a socket only on this and segments IV and V; 4 medium, similar to 4-II.

*Segment IV:* A short, stout, light brown color, less than twice the length of A-III; B long, averages six-branched; C long, averages seven-branched, range from five to nine; C' medium,

six-branched; 1 long, though a little shorter than 1-III, usually simple, occasionally two-branched; 2 small, two-forked; 4 medium, four-forked near base.

*Segment V*: A slightly longer than A-IV and similar; B long, four-branched; C averages four-branched, range from three to six; C' medium, three-forked near middle; 1 long, equal to 1-IV, always simple; 2 small, two-forked near middle; 4 medium, five-branched.

*Segment VI*: A almost twice the length of A-IV; B long, three-branched; C long, averages two-branched, range from one to three; C' medium, mesad of C, simple; 1 long, equal to 1-IV; 2

small, two-forked near middle; 4 medium, averages four-branched, range from two to five. *Segment VII*: A twice the length of A-IV, stout, acutely tapered from base, only rarely branched; B long, averages three-branched, range from two to four; C very long, simple; C' small, three- to four-forked; 1 small, simple; 2 small, two-forked near apex; 4 small, averages four-branched, range from three to five.

*Segment VIII*: A tufted, ten- to fifteen-branched; A' medium, averages three-branched, range from two to four.

*Paddle*: Midrib strong, nearly reaching apex; lateral margin and apex of medial margin with a fringe of fine hairs; terminal seta medium, simple; accessory seta small, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of six females from Lake Sentani, Dutch New Guinea, collected by Rozeboom, Knight, and Laffoon, USNM No. 2594.

#### Genus *BIRONELLA* Theobald

Since only two species of this genus have been completely described in the pupal stage it is impossible at the present time to formulate a diagnosis of the genus which will successfully separate it from *Anopheles*. *Bironella* (*Bru-gella*) *hollandi* Taylor is of doubtful occurrence in New Guinea; its pupa was completely figured and described by Belkin, Knight, and Rozeboom (1945: 244).

*Bironella* (*Bironella*) *soesiloi sensu* Swollen-grebel and Rodenwaldt 1932, as designated by Lee and Woodhill (1944: 65)

Fig. 11

**CEPHALOTHORAX.**—*Postocular*: 1 medium, three- or five-forked near base; 2 medium, six- to seven-forked near middle; 3 medium, six- to seven-forked near base.

*Anterothoracic*: 4 medium, four- to six-branched; 5 long, four- to six-forked near basal third; 6 medium, four-forked near middle; 7 long, six- to eight-forked near basal fourth.

*Dorsal*: 8 medium, simple or two-forked near apex.

*Supra-alar*: 9 long, three- to four-forked near middle.

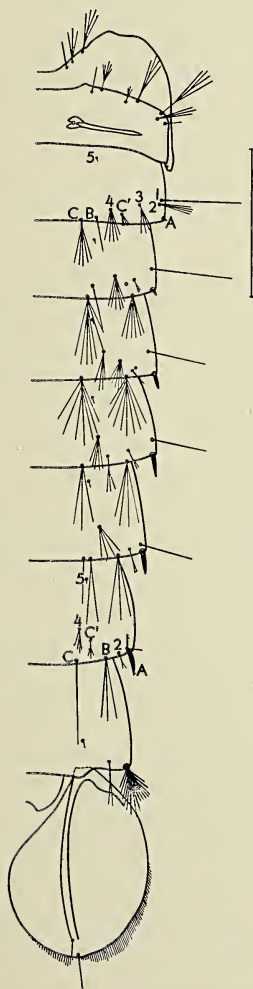


FIG. 10. *Anopheles koliensis*: dorsal aspect of right half of abdomen of female from Lake Sentani, Dutch New Guinea.



*Metanotum*: 10 medium, simple; 11 small, three-forked near base; 12 long, five- to six-forked near basal one-third.

**ABDOMEN.**—*Segment I*: H small, three- to six-forked near base; K small, three- to four-forked near basal one-third; L medium, four-forked near base; M small, averages five-forked, range from four to six; s long, four- to five-forked near basal one-third; T medium, four- to six-forked near basal one-third; U small, two- to five-branched.

*Segment II*: A very small, blunt-tipped, transparent; B medium, stout, with three or four fine side branches; C medium, averages twelve-branched, each branch of which may be split

into three or four smaller branches; C' small, two- to six-forked near apex; 1 long, averages five-branched, range from four to seven; 2 long, averages six-branched; 3 medium, seven- to nine-branched; 4 small, averages nine-branched; 5 minute, simple on this and all following segments.

*Segment III*: A small, about one and one-half times the length of A-II, blunt-tipped; B medium, eight- to twelve-branched; C long, ten- to eighteen-branched; C' medium, stout, with six to ten small side branches; 1 medium, five-branched; 2 small, with several small side branches or two-forked near apex; 3 represented only by its socket on this and segments IV and V; 4 medium, seven- to nine-branched.

*Segment IV*: A long, slightly curved and tapered to a fine point, about eight times as long as A-III; B medium, nine-branched; C long, averages ten-branched; C' small, six- to ten-branched; 1 medium, three-branched; 2 small, simple to three-forked near apex; 4 medium, six- to nine-branched.

*Segment V*: A as A-IV, about one and one-half times as long as A-IV; B long, averages eleven-branched; C long, averages eleven-branched; C' medium, two-branched; 1 medium, four-branched; 2 medium, three-branched; 4 small, six-branched.

*Segment VI*: A as A-V, but twice as long as A-IV; B long, averages eight-branched; C long, averages seven-branched; C' medium, simple; 1 medium, three-branched; 2 small, simple; 4 small, four- or five-branched.

*Segment VII*: A as A-VI, same length as A-VI; B long, averages five-branched; C medium, averages seven-branched; C' small, three-forked near middle; 1 small, three-branched; 2 small, simple; 4 small, six-branched.

*Segment VIII*: A slightly longer than A-VII, with eleven to nineteen side branches; A' medium, two- to four-forked near basal one-third.

*Paddle*: Midrib strong, reaching apex; almost the entire lateral and medial margins fringed with fine hairs; terminal seta long, simple, slightly hooked at apex; accessory seta small, three- to six-forked near middle.

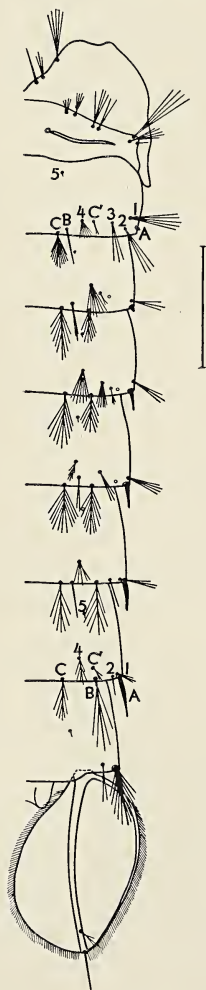


FIG. 11. *Bironella soesiloi*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.

**SPECIMENS EXAMINED.**—The pupal exuviae of one male and two females from Hilimoi, Milne Bay, Papua.

***Bironella (Bironella) gracilis* Theobald 1905**

The pupa of this species has not been described, but rather unsatisfactory figures of the paddles and trumpet were published by Hill (1925: 66).

**Genus *MEGARHINUS* Robineau-Desvoidy**

A diagnosis of the genus and a discussion of the species which occur in New Guinea are being reserved for a later study of the pupae of the tribe Megarhini.

***Megarhinus (Toxorhynchites) inornatus* Walker 1865**

The pupa of this species remains undescribed, but Hill (1925: 67) published figures of its terminal abdominal segments, the paddles, and the trumpet.

***Megarhinus (Toxorhynchites) splendens* (Wiedemann) 1819**

Brief superficial notes and figures of the pupa of this species were published by Banks (1908: 233) but are probably of no diagnostic value. Barraud (1931: 1131) included a few notes and figures of the paddle and part of segment VII based on specimens from India. Since Barraud was interested only in distinguishing among the Indian species of the genus, his key characters and descriptive notes which are quoted below are probably of little significance in New Guinea.

Paddle wide and rounded, less than  $1\frac{1}{2}$  times as long as greatest width; one of the five inner hairs near the posterior margin of tergite 7 very long and stout, reaching beyond the posterior margin of tergite 8. The larger lateral hair on segment 7 long and stout, usually much longer than tergite 8, and often as long as greatest width of paddle. Of the sub-median and sub-lateral hairs, one is long and black on tergites 2, 6 and 7, and two on tergites 3, 4 and 5; the larger hair on segments 2 to 7 is long.

**Genus *TRIPTEROIDES* Giles**

**DIAGNOSIS.**—Trumpets short with tracheoid portion reduced to a very small fraction of the base of the meatus. On segment I, setae H, K, and L placed about equidistant from each other. On segments II–VI, seta A a small lateral spine; A-VII and A-VIII large, fan-shaped plumose tufts. Seta B a long simple seta on segments II to VI. Paddles short, not exceeding the apices of setae A-VIII posteriorly; midrib weak; paddles without terminal setae; lateral face at least twice the width of medial face.

**Subgenus *RACHISOURA* Theobald**

The pupae of none of the fourteen New Guinean species of this subgenus are represented in our collections. However, Belkin (manuscript) completely described and figured two species from Guadalcanal, Solomon Islands, and thus provides us with at least a temporary diagnosis of the subgenus.

**DIAGNOSIS.**—Seta B-VII short, not more than one-half the length of segment VIII; seta B the most conspicuous seta on segment II, equal to or longer than seta 2-II; upper postocular seta (1) of cephalothorax simple.

**Subgenus *MIMETEOMYIA* Theobald**

**DIAGNOSIS.**—Seta B-VII short, not more than one-half the length of segment VIII; paddles tapering to a narrow blunt apex; seta 2 the most conspicuous seta on segment II, usually twice as long as B; upper postocular seta (1) of the cephalothorax two- or three-branched.

***Tripteroides (Mimeteomyia) argenteiventris* (Theobald) 1905**

Fig. 12

**CEPHALOTHORAX.** — *Postocular*: 1 long, usually two-branched, occasionally three-branched; 2 very long, two-branched; 3 small, simple or two-forked.

*Anterotheracic*: 4 medium, usually two-forked near base, occasionally simple; 5 medium, two-forked; 6 medium, simple; 7 long, simple.

*Dorsal*: 8 long, usually simple, occasionally two-forked.



*Supra-alar*: 9 long, simple.

*Metanotum*: 10 two- or three-forked, occasionally simple or four- to five-forked; 11 simple; 12 simple.

*Trumpet*: short, funnel-shaped, greatest diameter equal to a little less than half the length; pigmentation uniform; pinna equal to about two-fifths of total length; no definite tracheoid portion present.

**ABDOMEN.**—*Segment I*: H small, simple; K long, simple; L medium, usually two-forked from near base, occasionally three- or four-forked; M very small, usually simple, ranges from simple to four-forked; S and T long, subequal to each other, simple; U minute, simple.

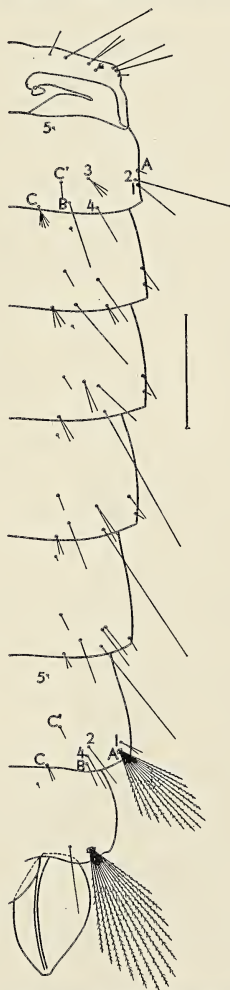


FIG. 12. *Tripteroides argenteiventris*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

*Segment II*: A small, simple spine; B long, simple; C small, three- to seven-forked near base; C' small, simple; 1 medium, simple or two-forked; 2 longest seta on segment, simple; 3 small, two- to five-forked; 4 medium, usually simple, occasionally two- or three-forked.

*Segment III*: A small, simple spine; B long, simple; C small, usually three-forked near base, occasionally simple or four- to five-forked; C' small, simple; 1 small, simple; 2 small, two- or three-forked, rarely simple; 3 represented only by its socket; 4 medium, simple.

*Segment IV*: A small, simple spine; B very long, exceeding posterior margin of segment V, simple; C small, two- to three-forked near base, or occasionally four-forked; C' small, simple; 1 small, simple; 2 medium, simple; 3 represented only by its socket; 4 medium, usually two-forked from near base, occasionally simple or three-forked.

*Segment V*: A small, simple spine; B very long, equal to B-IV, simple; C small, usually two-forked near base, or occasionally simple or three-forked; C' small, simple; 1 small, simple; 2 medium, usually two-forked near base, occasionally three-branched; 3 represented by its socket; 4 medium, simple.

*Segment VI*: A small, simple spine; B long, not quite reaching posterior margin of segment VII, simple; C small, usually simple, occasionally two- to three-forked from middle; C' small, simple; 1 medium, well removed from the lateral margin, simple; 2 medium, simple; 3 absent; 4 medium, simple.

*Segment VII*: A large, black, conspicuous nine- to fourteen-branched, plumose tuft, usually twelve-branched, about equal to B-VI in length; B small, simple; C small, either simple or two-forked; C' small, simple; 1 small, simple or two- to three-forked near apex; 2 medium, simple; 4 medium, simple.

*Segment VIII*: A very large, black, conspicuous thirteen- to twenty-two-branched, plumose tuft, averages seventeen-branched, exceeding the paddles in length; A' long, reaching to about the middle of the paddle, simple.





*Segment III:* A small, simple; B long, stout, simple; C small, simple; 1 small, simple, rarely two-branched; 2 small, two-branched or occasionally simple or three-branched; 3 represented only by its socket on this and segments IV and V; 4 small, two-branched, occasionally three-branched.

*Segment IV:* A small, simple; B long, stout, simple; C small, two-branched, rarely three-branched; C' small, simple; 1 small, simple or two-branched; 2 small, two-branched, or occasionally three-branched; 4 small, two- or three-branched, or occasionally simple or four-branched.

*Segment V:* A small, simple; B long, stout, simple; C small, two-branched or occasionally simple or three-branched; C' small, simple; 1 small, simple or occasionally two-branched; 2 small, three-branched, range from simple to four-branched; 4 small, simple, rarely two-forked.

*Segment VI:* A small, simple; B long, stout, simple; C small, two-branched, range from simple to three-branched; C' small, simple; 1 small, simple or rarely two-branched; 2 small, two-branched or occasionally simple or three-branched; 3 absent; 4 small, simple or rarely two-forked.

*Segment VII:* A large, conspicuous, fan-like, eight- to thirteen-branched, plumose tuft, usually nine- or ten-branched; B long, about twice the length of A, stout, simple; C small, simple, rarely two-branched or three-forked; C' small, simple; 1 small, stout, four-branched, occasionally three- or five-branched; 2 small, simple, rarely two-branched; 4 small, simple.

*Segment VIII:* A large, conspicuous, fan-like, ten- to twenty-branched, plumose tuft exceeding the apices of the paddles in length, averages seventeen-branched; A' small, simple.

*Paddles:* Short, generally blunt-tipped, almost squared; not exceeding the branches of A-VIII in length; margins smooth, lacking terminal setae; midrib not quite reaching apex, dividing paddle unequally, the lateral face being about three times as wide as the medial face.

**SPECIMENS EXAMINED.**—The pupal exuviae of four males and six females from Hilimoï and

KanaKope, Milne Bay, Papua, and Amsterdam Island, Dutch New Guinea.

**Tripteroides (Tripteroides) brevipalpis**  
Brug 1934

Fig. 14

**CEPHALOTHORAX.**—*Postocular:* 1 very long, about twice length of trumpet, two-branched; 2 long, two-branched; 3 long, three-branched.

*Anterothoracic:* 4 medium, two- or three-branched; 5 long, three-branched; 6 small, simple; 7 medium, two-branched.

*Dorsal:* 8 long, slightly longer than trumpet, two-branched.

*Supra-alar:* 9 medium, two-branched.

*Metanotum:* 10 small, two-branched, occasionally simple or three-branched; 11 long, simple; 12 long, two- or three-forked, occasionally simple, usually slightly plumose.

*Trumpet:* Funnel-shaped, length about four and one-half times the greatest diameter of the meatus; pinna about one-fourth of the total length; tracheoid area represented by only two or three rings at base; darkest pigment near middle, both ends lighter.

**ABDOMEN.**—*Segment I:* H small, simple; K long, stout, simple; L small, simple or rarely two- or three-forked; M small, usually two- or three-branched, range from simple to four-branched; S and T long, simple, subequal in length; U minute, simple.

*Segment II:* A very small, simple; B long, stout, simple; C small, three-branched, occasionally two- to five-branched; C' small, simple on this and all following segments; 1 small, simple; 2 long, stout, simple, subequal to B; 3 small, three-branched, range from simple to four-branched; 4 small, two- or three-branched, range from two- to four-branched.

*Segment III:* A very small, simple; B long, stout, simple; C small, three-branched, range from two- to four-branched; 1 small, two-branched or rarely three-branched; 2 small, two-branched, occasionally simple or three-branched; 3 represented only by its socket on this and segments IV and V; 4 small, two- or three-branched, range from two- to five-branched.



*Segment IV*: A very small, simple; B long, stout, simple; C small, three- or four-branched, rarely five-branched; 1 small, two- or three-branched; 2 small, two-branched or occasionally simple or three-branched; 4 small, two- or three-branched, range from simple to four-branched.

*Segment V*: A very small, simple; B long, stout, simple; C small, three- or four-branched; 1 small, two- or three-branched; 2 small, three-branched, range from two- to four-branched; 4 small, simple.

*Segment VI*: A very small, simple; B long, stout, simple; C small, three-branched or occasionally two- or four-branched; 1 small, two- or three-

branched; 2 small, three-branched, range from simple to three-branched; 3 absent; 4 small, simple.

*Segment VII*: A large, conspicuous, fan-like, ten- to seventeen-branched, plumose tuft, usually thirteen-branched; B very long, stout, simple; C small, two- to four-branched; 1 small, stout, four- or five-branched, occasionally three- or six-branched; 2 small, simple or occasionally two-branched or forked; 4 small, simple or occasionally two-branched or forked.

*Segment VIII*: A large, conspicuous, fan-like, fifteen- to twenty-one-branched, plumose tuft exceeding the apices of the paddles in length, usually twenty-branched; A' small, simple.

*Paddles*: Short, generally blunt-tipped and not exceeding the branches of A-VIII in length; margins smooth; without terminal setae; mid-rib not quite reaching apex, dividing the paddle unequally, the lateral face being about three times the width of the medial face.

**SPECIMENS EXAMINED**.—The pupal exuviae of four males and four females from Mios Woendi, Dutch New Guinea.

#### Genus *HARPAGOMYIA* De Meijere

**DIAGNOSIS**.—Trumpet very short, with small, almost circular opening; outer wall wholly reticulate, the thin inner wall more obviously separated from the outer wall than usual, its basal part with some annular ridges. Upper postocular seta (1) of cephalothorax very long, split to the base into two equally stout branches; dorsal seta (8) placed well behind trumpets. Abdomen with setae H and K not far apart, K long and simple, all the other setae (including s) quite small. Setae A and B on segment II long and simple; C not quite so long, forked above base. Setae A and C on III–VI small; B long and simple, increasing in length from segment III to VI. Setae A–VII and A–VIII forming large fan-shaped tufts, largest on VIII and slightly shorter than paddle in length. Paddles small, broad at base and pointed at tip, without terminal setae, medial face rather narrow.

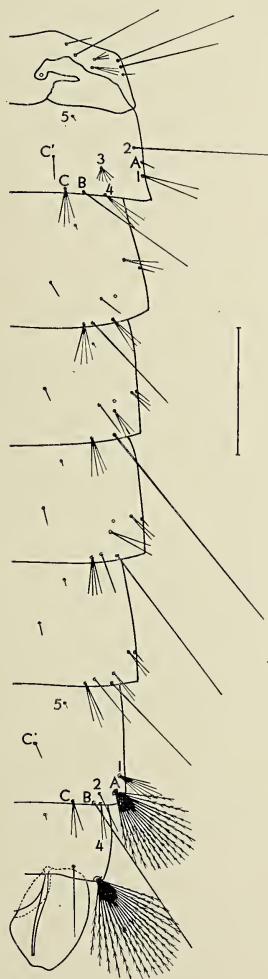


FIG. 14. *Tripteroides brevipalpis*: dorsal aspect of right half of abdomen of female from Mios Woendi, Dutch New Guinea.



*Harpagomyia genurostris* (Leicester) 1908

Our pupal specimens of this species from Saidor, Northeast New Guinea, were lost due to breakage in shipment, hence a complete description cannot be given. However, this is the only species of the genus known from New Guinea so the generic diagnosis should be sufficient to place any specimens from the island.

The species has been partially described but inaccurately figured by Jacobson (1911: 161) and De Meijere (1911: 164) from the Dutch East Indies and partially figured but not described by Bohart and Ingram (1946: 54) from Okinawa. The following descriptive notes have been translated and rewritten from De Meijere.

**CEPHALOTHORAX.**—Behind the upper eye-spot stands a long double hair (median post-ocular seta), which beyond the middle shows a strong bending; under the eye one finds a much shorter, simple or double seta (upper post-ocular). The thorax also bears in front two short double hairs, one behind the other (upper and lower anterothoracic). On the middle, also, are the respiratory trumpets. These are long, in the upper half almost entirely of equal width, straight truncate at the end, and with a few deep incisions on the inner side.

**ABDOMEN.**—On the last abdominal segment are the customary, well-developed, multifid fan-hairs (A-VIII). The dorsum always shows more hairs close to the corner, which are mostly sessile, those lying on the lateral sides (evidently seta B) are particularly long and surpass the next following segment in length. The next to the last and the last segments always bear a multifid fan-hair on the posterior outer corner. The paddles are little pigmented, with an inconspicuous midrib, long and acuminate apically, terminal seta missing, the margin is extremely fine-toothed on the medial side only, the rest smooth. The abdomen is yellow-white, while on the back it has a characteristic black pattern.

Genus *HODGESIA* Theobald

**DIAGNOSIS.**—Readily distinguished from all other mosquito pupae by the form of the trumpets, which are described by Wigglesworth (1929: 60) as follows:

Trumpets small and of highly characteristic structure, being cleft almost to the base in the form of two leaflets. Outer leaflet four times as long as its average width, with more or less longitudinal strigulae and with numerous minute scale-like denticles on the outer surface. Inner leaflet only half the width of the outer and with a bifid tip; it has the same longitudinal or oblique strigulation, but is without the minute denticles of the outer leaflet; its anterior margin and tip are clothed with fine hairs and the posterior margin is reflected inwards away from the outer leaflet.

The cephalothoracic and almost all the abdominal setae are small and inconspicuous. The dorsal seta (8) of the cephalothorax is placed in front of the trumpets.

The pupa of none of the three New Guinean species has been described.

Genus *URANOTAENIA* Lynch-Arribalzaga

**DIAGNOSIS.**—As in culicine genera the inner wall of the trumpet is not separated from the outer (in contrast to *Harpagomyia*), and the following features are found in the abdominal chaetotaxy. Setae H and K close together, but well apart from L and M; s somewhat larger than these; the float-hair usually large and dendritic. Seta 2-II long, markedly longer than other setae of the segment. Setae A-III through VI small and spine-like; A-VII and A-VIII very variable according to the species. Segment IX always with a small seta on its posterolateral corners.

**DISCUSSION.**—As noted by Edwards (1941: 364) it is surprising that the pupal stage of *Uranotaenia* is not better defined in view of the distinctive position of the genus on adult characters. Perhaps the readiest means of diagnosis is the pair of setae on segment IX which are always at least equal to the length of that segment; these setae are also present in *Aedo-*

*myia* and in most, if not all, *Culex*, but in these genera they are shorter, stout, and often difficult to see. The paddles of *Uranotaenia* usually have the medial face much wider than the lateral face, but this is not a constant feature. The dorsal setae (8) of the cephalothorax are placed between the trumpets in most *Uranotaenia* as in most *Aedes*, not behind them as in *Megarrhinus*, *Harpagomyia*, *Ficalbia*, and, usually, *Culex*, but this feature is not quite constant either. In most of the species, one of the anterothoracic setae (seta 6 in the known New Guinean species) is lengthened and thickened.

Key to Species of *Uranotaenia*

- 1. Trumpets short, their total length less than three times the greatest diameter of the meatus; tracheoid area greatly reduced, comprising less than one-fifth the total length of the trumpet..... 2  
..... (Subgenus *Pseudoficalbia*)
- Trumpets moderate to very long, their total length more than four times the greatest diameter of the meatus; tracheoid area not reduced, comprising more than two-fifths of the total length of the trumpet..... 4  
..... (Subgenus *Uranotaenia*)
- 2. Setae A-VII and A-VIII long, at least equal to the length of their respective segments, two- or three-branched; seta B on segments IV-VII long, more than one-half the length of the segments; with an irregular line of black pigment on base of paddle (Fig. 15)..... *U. papua*  
Setae A-VII and A-VIII short, not more than one-half as long as their respective segments, always simple; seta B on segments IV-VII short, always less than one-half the length of the segments; paddle without pigment..... 3
- 3. Seta 1 on segment II three- or four-branched (Fig. 16)..... *U. nigerrima*  
Seta 1 on segment II simple..... *U. quadrimaculata*
- 4. Seta B on segments V-VII very long, greatly exceeding length of segments, two- or three-branched (Fig. 17)..... *U. albescens*  
Seta B on segments V-VII long, exceeding length of segment only slightly on V, not exceeding segment on VI and VII, usually three- or four-branched (Fig. 18)..... *U. argyrotarsis*

*Uranotaenia* (*Pseudoficalbia*) *papua* Brug 1924

Fig. 15

DIAGNOSIS.—With the typical characteristics of the subgenus. Readily separated from other known *Pseudoficalbia* from New Guinea in having setae A-VII and A-VIII longer and two- to three-branched and seta B on segments IV-VII more than one-half the length of the segment.

CEPHALOTHORAX.—*Postocular*: 1 medium, simple; 2 small, two-branched; 3 small, two-branched.

*Anterotheracic*: 4 small, simple; 5 small, four-branched; 6 long, greater than length of trumpet, stout, simple; 7 small, three-branched.

*Dorsal*: 8 long, three-fifths length of trumpet, two-branched.

*Supra-alar*: 9 small, simple or two-branched.

*Metanotum*: 10 long, simple; 11 long, simple; 12 medium, simple.

*Trumpet*: Short, total length about two and one-third times the greatest diameter of the meatus; pinna short, less than one-fourth of the total length; tracheoid area reduced to basal one-fifth of trumpet, with a small spot of dark pigment.

ABDOMEN.—*Segment I*: H small, simple; K long, stout, simple; L small, simple or two-forked; M small, two-forked or branched, occasionally simple or three-branched; S long, simple; T small, two-branched or forked, occasionally simple or three-branched; U small, simple.

*Segment II*: A small, simple spine; B long, simple; C medium, simple; C' medium, simple or rarely two-branched; 1 medium, two-branched; 2 long, simple; 3 small, simple or occasionally three-branched or forked; 4 medium, simple; 5 medium, simple on this and all following segments.

*Segment III*: A small, simple; B medium, simple; C medium, simple or occasionally two-forked; C' small, simple on this and all following segments; 1 medium, simple; 2 small, simple or two-forked near base; 3 represented only by its socket on this and segments IV and V; 4 small, simple.



*Segment IV:* A medium, simple; B long, simple; C medium, simple or occasionally two-branched; 1 medium, simple; 2 small, two-branched or forked near base, occasionally simple; 4 small, simple or two-forked, occasionally three- or four-forked.

*Segment V:* A medium, simple; B long, simple; C small, simple; 1 medium, simple or two-forked, occasionally three- or four-forked; 2 small, simple or two-branched, occasionally three-forked; 4 small, simple or two-forked, occasionally three-forked.

*Segment VI:* A long, simple or occasionally with a small side branch; B long, simple; C small,

simple; 1 medium, two-branched or forked near base, occasionally simple or three-branched; 2 small, simple or two-branched; 3 absent; 4 medium, simple or two-branched, occasionally three-branched.

*Segment VII:* A very long, reaching posterior margin of segment VIII, usually two-branched, only rarely simple; B long, simple; C medium, simple; 1 very small, well removed from lateral margin, usually simple, occasionally two-branched; 2 small, simple or two-forked; 4 small, simple or two-forked.

*Segment VIII:* A very long, strong, two-branched or rarely three-branched; A' medium, simple or occasionally two- to four-forked.

*Segment IX:* v medium, stout, simple.

*Paddle:* Roughly oval, length greater than width; margin of apical one-half finely serrate laterally, coarsely serrate medially; midrib strong, dividing the paddle unequally, the lateral face being about two-thirds the greatest width of the medial face; with an irregular line of black pigment across the base of the paddle; terminal seta medium, simple; accessory seta small, about one-half length of terminal seta, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of twelve males and seven females from Hili-moi, Milne Bay, Papua; Draeger Harbor, Northeast New Guinea; and Mios Woendi, Dutch New Guinea.

*Uranotaenia (Pseudoficalbia) nigerrima*  
Taylor 1914

Fig. 16

**DIAGNOSIS.**—With the typical characteristics of the subgenus *Pseudoficalbia*: trumpets short, their total length about two and one-fourth times the greatest diameter of the meatus; tracheoid area reduced to only a few basal rings; with both terminal and accessory setae on paddles. Setae A-VII and A-VIII, as well as seta B on segments IV-VII, short, less than one-half the length of their respective segments. Very similar to *U. quadrimaculata*, but separable from it in having seta 1 on segment II three- or four-branched while on *quadrimaculata* this seta is simple.

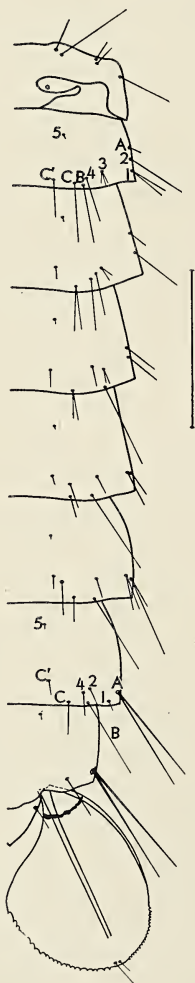


FIG. 15. *Uranotaenia papua*: dorsal aspect of right half of abdomen of male from Mios Woendi, Dutch New Guinea.



**CEPHALOTHORAX.**—*Postocular*: 1 medium, simple; 2 small, three-forked; 3 medium, two-branched.

*Anterothoracic*: 4 medium, two- or three-forked near apex; 5 medium, four-branched; 6 long, stout, simple; 7 small, two- or three-forked.

*Dorsal*: 8 long, two-thirds length of trumpet, three- or four-branched.

*Supra-alar*: 9 long, simple.

*Metanotum*: 10 medium, stout, simple or two-forked; 11 long, stout, simple; 12 long, slender, simple.

*Trumpet*: Short, length about two and one-fourth times the greatest diameter of the meatus; pinna short, about one-third of total length; tracheoid area reduced to three or four basal rings; with a small spot of dark pigment in the tracheoid area.

**ABDOMEN.**—*Segment I*: H medium, simple; K long, stout, simple; L small, simple; M small, two- or three-branched or only rarely simple or four-branched; S small, simple; T small, two- to four-branched; U minute, simple.

*Segment II*: A small, simple spine; B medium, stout, simple; C medium, stout, two-forked or occasionally simple or three-forked; C' medium, simple spine; 1 medium, three-branched or occasionally two- to four-branched or rarely simple; 2 small, stout, simple; 3 very small, two-branched or occasionally simple or three-branched; 4 medium, stout, simple; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B medium, stout, simple; C small, two-branched or occasionally simple or three-branched; C' small, simple on this and all following segments; 1 small, simple or occasionally two-branched or forked; 2 small, two-forked, occasionally simple or two-branched; 3 represented only by its socket on this and segments IV and V; 4 medium, stout, simple.

*Segment IV*: A small, simple spine; B medium, stout, simple; C small, two-branched or occasionally simple to four-branched; 1 small, simple or two-branched; 2 small, two-branched or occasionally simple; 4 small, three-branched, range from two- to four-branched.

*Segment V*: A small, stout, simple spine; B medium, stout, simple; C small, two-branched or occasionally simple or three-branched; 1 small, simple or occasionally two-branched or two-forked; 2 small, two- or three-branched; 4 small, two-branched or occasionally three-branched.

*Segment VI*: A small, stout, simple spine; B medium, stout, simple; C small, two-branched or occasionally simple to four-branched; 1 small, simple; 2 small, two-branched, range from simple to three-branched; 3 absent; 4 small, two-branched or forked, range from simple to three-branched.

*Segment VII*: A small, stout, simple; B medium, stout, simple; C small, two-branched or occasion-

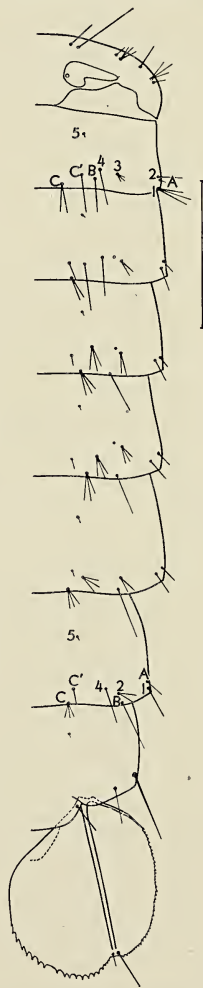


FIG. 16. *Uranotaenia nigerrima*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.

ally simple or three-branched; 1 small, simple; 2 small, simple or two-branched; 4 small, simple or two-branched.

*Segment VIII*: A medium, stout, simple; A' small, simple or rarely two-branched.

*Segment IX*: v small, stout, simple.

*Paddle*: Rounded, length slightly exceeding greatest width; margin finely serrate laterally, more coarsely serrate medially; apex notched at end of midrib; midrib strong, almost reaching apex, dividing paddle unequally, the lateral face approximately two-thirds the width of the medial face; without pigment; terminal seta very small, simple; accessory seta medium, stout, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of nine males and twelve females from Gamadodo and Hilimoi, Milne Bay, Papua, and Draeger Harbor, Northeast New Guinea.

***Uranotaenia (Pseudoficalbia) quadrimaculata*** Paine and Edwards 1929

Pupa described diagnostically without figures by Paine and Edwards (1929: 313) from Guadalcanal, Solomon Islands. Since we have no New Guinean specimens in our collections the following descriptive notes have been taken entirely from the above paper.

**DIAGNOSIS**.—With the typical characters of the subgenus. Very close to *U. nigerrima*, but apparently separable from it in having seta 1 on segment II simple.

**CEPHALOTHORAX**.—*Dorsal*: 8 three- to four-branched, placed behind trumpet.

*Trumpet*: Short, only about twice as long as its greatest breadth; on the middle of inner margin is a small, semicircular emargination.

**ABDOMEN**.—*Segment II*: 1 and 2 strong, simple, placed close together near lateral margin. *Segments III–VII*: "Each with short stiff bristle laterally, somewhat behind the posterior corner, and a simple sublateral bristle, about two-thirds as long as the segment on posterior margin; remaining bristles on segment minute and inconspicuous, except that segment VII has additional simple bristle at posterior corner."

*Segment VIII*: A simple or bifid.

*Paddle*: "With the part within midrib much longer than the outer part, also more extended apically, where it is provided with a loose fringe of spinules; on outer part of paddle the spiny fringe is much shorter and closer." Terminal seta small, simple; accessory seta longer, simple.

***Uranotaenia (Uranotaenia) albescens*** Taylor 1914

Fig. 17

**CEPHALOTHORAX**.—*Postocular*: 1 medium, eleven-forked; 2 medium, six-forked; 3 medium, five-forked.

*Anterotheracic*: 4 medium, four- to five-forked; 5 long, three-branched; 6 very long, stout, simple; 7 medium, three-forked.

*Dorsal*: 8 very long, plumose, simple or two-branched.

*Supra-alar*: 9 missing from specimen.

*Metanotum*: 10 fairly long, three-branched; 11 fairly long, three-forked; 12 fairly long, five- to seven-branched.

*Trumpet*: Long, tubular, length about ten times the greatest diameter of the meatus; pinna short, expanded at tip; tracheoid portion dark, remainder of trumpet pale.

**ABDOMEN**.—*Segment I*: H long, simple; K long, two-forked near middle; L very small, three- to five-forked near middle; M small, simple or two-forked; s long, two-forked near base; r medium, simple; u small, two-forked.

*Segment II*: A medium or small, simple; B long, two-forked near middle; C long, eight-branched; C' small, three- or four-forked near apex; 1 medium, three-forked near middle; 2 long, two-branched, most conspicuous seta on the segment; 3 medium, three-forked near base; 4 long, simple; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B medium, three-forked near middle or simple; C long, with eight branches; C' very small, simple or two-branched; 1 long, three-branched; 2 small, simple; 3 represented only by its socket on this and segments IV and V; 4 small, five-branched.

*Segment IV*: A small, simple spine; B long, four-branched; C long, five- to six-branched; C' very



small, simple; 1 medium, three-branched; 2 small, simple; 4 medium, four- or five-forked near middle.

*Segment V*: A small, simple spine; B very long, exceeding posterior margin of segment VI, three-branched; C similar to B but shorter, four-branched; C' very small, simple; 1 medium, three-branched; 2 small, three- or four-forked near apex; 4 small, simple.

*Segment VI*: A small, simple spine; B very long, equal to B-V, three-branched; C long, equal to C-V, four-branched; C' very small, simple; 1 medium, three-branched; 2 medium, simple or three-forked near apex; 3 absent; 4 medium, simple.

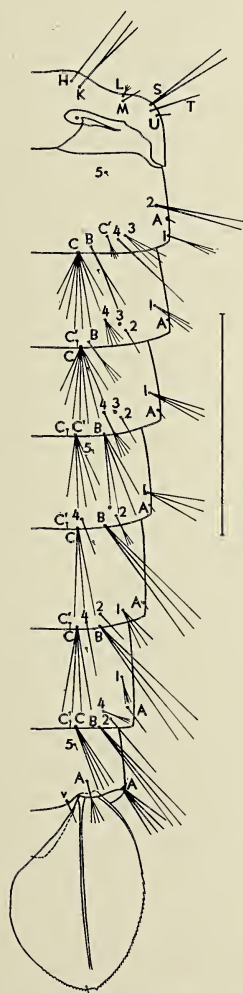


FIG. 17. *Uranotaenia albescens*: dorsal aspect of right half of abdomen of male from WagaWaga, Papua.

*Segment VII*: A medium, simple; B very long, similar to B-VI, two- or three-branched; C long, four-branched; C' very small, simple; 1 small, four-forked near middle; 2 long, simple or three-forked near apex; 4 small, three- or four-forked near apex.

*Segment VIII*: A medium, stout, four- or five-branched; A' medium, four-forked near middle.

*Segment IX*: v small, stout, simple.

*Paddle*: Long, oval; margin of apical two-thirds serrate laterally, only apical one-third serrate medially; midrib strong, dividing paddle unequally, the lateral face a little more than one-half as wide as the medial face; terminal seta minute, simple; accessory seta absent.

**SPECIMEN EXAMINED.**—The pupal exuvium of a single male from WagaWaga, Milne Bay, Papua.

*Uranotaenia (Uranotaenia) argyrotarsis*  
Leicester 1908

Fig. 18

This pupa was partially described, without figures, by Paine and Edwards (1929: 312) from the Solomon Islands.

**CEPHALOTHORAX.** — *Postocular*: 1 long, seven- or eight-forked near base, rarely less; 2 long, slightly shorter than 1, usually eight-forked near base, rarely six-forked; 3 long, usually six-forked near base, rarely three-forked.

*Anterothoracic*: 4 long, six- or five-forked near base; 5 medium, four-forked near base; 6 very long, stout, exceeding length of trumpet, simple; 7 medium, two- or three-forked near middle.

*Dorsal*: 8 very long, about equal to trumpet in length, five- to eight-forked near base.

*Supra-alar*: 9 small, three- to five-forked near base.

*Metanotum*: 10 small, three- to four-forked near base; 11 small, two-forked near middle; 12 long, three- to five-forked near base.

*Trumpet*: Moderately long, total length about four and one-half times greatest diameter of meatus; uniformly dark pigmented.

**ABDOMEN.**—*Segment I*: H medium, simple; K medium, three-forked near base; L small,

simple or two- to three-forked at apex; M small, three- to four-forked near base, rarely five-forked; s long, usually three-forked near base, rarely simple or two-forked; T medium, two- to four-forked near basal one-fourth; U very small, simple.

*Segment II:* A small, simple spine; B medium, usually three-forked near base, rarely simple or two-forked; C medium, three- to five-forked basally, each branch itself being forked further out; C' medium, three- to four-forked; 1 medium, two- or three-forked near basal one-fourth; 2 long, two-forked near base; 3 small, two- or three-forked near apex, rarely simple; 4

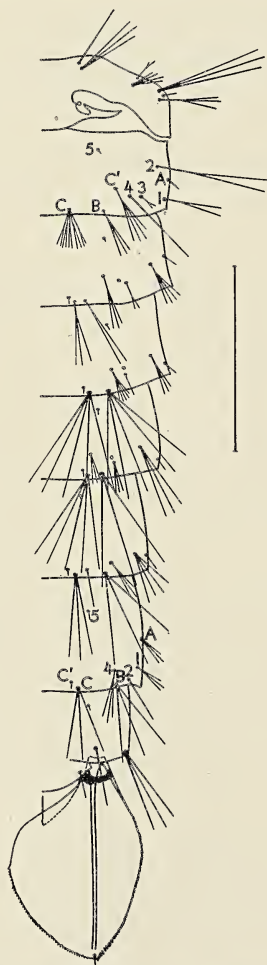


FIG. 18. *Uranotaenia argyrotarsis*: dorsal aspect of right half of abdomen of male from WagaWaga, Papua.

long, simple; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B medium, two- or three-forked near base, rarely simple; C medium, three- to six-forked near base; C' small, simple on this and all following segments except VIII from which it is absent; 1 medium, usually two-forked, occasionally three- or four-forked; 2 small, two-forked near apex; 3 represented only by its socket; 4 medium, four- to five-forked near base.

*Segment IV:* A small, simple spine; B long, reaching to anterior part of segment VI, four- or five-branched, rarely three-branched; C similar to B, five- or six-branched; 1 small, three- or four-forked near base; 2 very small, simple or rarely three-forked near apex; 3 represented only by its socket; 4 small, two- to five-forked near basal one-fourth.

*Segment V:* A small, simple spine; B similar to B-IV, three- or four-branched; C similar to C-IV, three- to six-branched, usually five; 1 long, three- or four-forked near base; 2 small, three- to five-forked near base; 3 represented only by its socket; 4 small, two- or three-forked near base.

*Segment VI:* A small, simple spine; B similar to B-V, but not quite as long, three- or four-branched; C similar to C-V but not as long, three- or four-branched; 1 medium, three- or four-forked near base; 2 small, two- to four-forked near basal one-fourth; 3 absent; 4 small, usually simple, occasionally two- or three-forked near apex.

*Segment VII:* A small, three-branched; B similar to B-VI, two- to five-branched; C similar to C-VI, two- to four-branched; 1 small, three-forked near base; 2 medium, usually simple, occasionally two-forked near apex; 4 medium, three- to five-forked near base.

*Segment VIII:* A medium-long, two- or three-branched; A' medium, two-forked near apex or simple.

*Segment IX:* v small, simple.

*Paddle:* Elongate, more or less pointed; margin very finely serrate laterally, becoming coarser



apically and medially; midrib strong, dividing paddle unequally, the lateral face about one-half the width of the medial face; with an irregular bar of black pigment across the base of the paddle; terminal seta minute, very difficult to see on some specimens, simple; accessory seta absent.

**SPECIMENS EXAMINED.**—The pupal exuviae of six males and eleven females from Gamadodo, WagaWaga, and Hilimoi, Milne Bay, Papua.

***Uranotaenia (Uranotaenia) neotibialis* King and Hoogstraal 1947**

Pupal trumpet described and figured by King and Hoogstraal (1947: 590) from Hollandia, Dutch New Guinea, as follows: "Moderately long, length .46 mm., diameter .043 at narrowest point, pigmented apically and on basal half."

***Uranotaenia (Uranotaenia) setosa* King and Hoogstraal 1947**

Pupal trumpet described and figured by King and Hoogstraal (1947: 585) from Hollandia, Dutch New Guinea, as follows: "Long and slender (length .58 mm.; width at narrowest point .028 mm.), somewhat flared at tip, pigmented apically and on basal two-fifths."

***Uranotaenia (Uranotaenia) tibioclada* King and Hoogstraal 1947**

Pupal trumpet described and figured by King and Hoogstraal (1947: 593) from Dobodura, Northeast New Guinea, as follows: "Very long and slender, length 1.05 mm., diameter .05 at narrowest point; pigmented on basal half and at apex."

### Genus *FICALBIA* Theobald

**DIAGNOSIS.**—According to Edwards (1941: 374) the species of *Ficalbia* are so diverse in the pupal stage that it is difficult to give an adequate generic diagnosis that will apply to all of them. Two characters common to all known species are: trumpets with at least the basal one-half (usually much more) tracheoid; paddles narrow at the base and without buttress.

### Subgenus *MIMOMYIA* Theobald

**DIAGNOSIS.**—The following characters are common to all known species. Trumpets long, with more than proximal one-half tracheoid. Float-hair fully developed or reduced but always branched. Dorsal seta (8) of cephalothorax not stout, usually multiple and always inserted far behind the trumpets. Main abdominal setae sometimes forming large tufts but not conspicuously black. On segments III–VII, seta *C'* is on the margin internal to *C*; on VII, setae 2 and 4 are both absent. Segment VIII is longer than in most culicine pupae, being almost as long as broad; seta A–VIII very small and inconspicuous.

The pupae of the two species recorded from New Guinea remain unknown.

### Subgenus *ETORLEPTIOMYIA* Theobald

**DIAGNOSIS.**—In all the four known species of this subgenus the trumpets are very long, slender, and flexible, and are tracheoid for more than three-fourths of their length. The dorsal seta (8) of cephalothorax is placed far behind the base of the trumpets as in the subgenus *Mimomyia*, but it is stout or very stout in *Etorleptiomyia*. The float-hair is reduced to a small, stout, simple seta. The abdomen has many strong black tufts, including A–VIII. The paddles are at least five times as long as their greatest width with both margins strongly denticulate and with no setae at tip. On segments IV–VI, seta *C'* is on the posterior margin between B and C.

***Ficalbia (Etorleptiomyia) elegans* (Taylor) 1914**

Fig. 19

The pupa was described without figures by Taylor (1929: 271) from Townsville, Australia.

**CEPHALOTHORAX.**—*Postocular*: 1 medium, simple; 2 small, simple; 3 long, simple.

*Anterothoracic*: 4 small, simple; 5 small, simple; 6 very long, simple; 7 small, simple.

*Dorsal*: 8 medium, stout, black, far behind trumpets.

*Supra-alar*: 9 small, two- or three-forked near middle.

*Metanotum*: 10 very long, black, simple; 11 long, simple; 12 small, two-forked near middle, pale.

*Trumpet*: Very long, tubular, equal to length of abdominal segments I–VIII; tracheoid portion extending over three-fourths of the length of the trumpet, darkly pigmented; pinna short, slightly flared, pale colored along with reticulate portion.

**ABDOMEN.**—*Segment I*: H very long, simple; K very long, simple; L small, two-forked; M long, simple; s long, simple; T small, simple; U small, simple; float-hair small, stout, simple.

*Segment II*: A short, simple spine; B very long, simple; C very long, two-branched; 1 medium, simple; 2 small, three-forked; 3 long, two-branched; 4 long, simple.

*Segment III*: A short, simple spine; B very long, simple; C very long, four-branched; C' short, simple; 1 medium, simple; 2 long, simple; 3 represented only by its socket on this and segments IV and V; 4 long, two-branched.

*Segment IV*: A short, simple spine; B very long, three-branched; C very long, five-branched; C' small, simple; 1 medium, simple; 2 long, simple; 4 long, simple.

*Segment V*: A short, simple spine; B very long, three-branched; C very long, four-branched; C' small, simple; 1 a little longer than 1-IV, simple; 2 small, simple; 4 small, simple.

*Segment VI*: A short, simple spine; B very long, three-branched; C very long, four-branched; C' small, simple; 1 medium-long, simple; 2 small, simple; 3 absent; 4 small, simple.

*Segment VII*: A short, simple spine; B very long, three-branched; C exceedingly long, reaching to middle of paddle, three-branched; C' small, simple; 1 medium, three-branched; 2 small, simple; 4 small, simple.

*Segment VIII*: A very long, eight-branched; A' small, two-forked.

*Paddle*: Long and narrow, length about seven times greatest width; with a pale brownish tint except on the apical third; midrib well developed; without terminal setae; margin with a

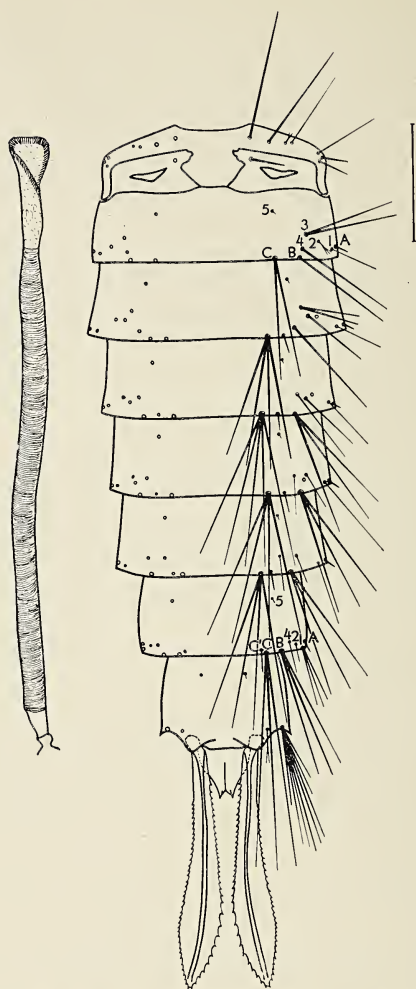


FIG. 19. *Ficalbia elegans*: pupal trumpet and dorsal aspect of abdomen of male from Chacon Swamp, Guadalcanal, Solomon Islands.

fringe composed of tooth-like processes extending right around the apex, the processes increasing in size from the base to the apex, especially on the medial margin.

**SPECIMENS EXAMINED.**—The pupal exuviae of one male and one female from Chacon Swamp, Guadalcanal, Solomon Islands, collected by John N. Belkin.



FIG. 20. *Mansonia*, subgenus *Coquilleltidia*: characteristic trumpet (after Edwards, 1941).



Genus *MANSONIA* Blanchard

**DIAGNOSIS.**—The two main features by which pupae of *Mansonia* differ from those of other mosquitoes are the modification of the tip of the trumpet for the purpose of piercing plant roots and the replacement of the float-hairs by minute simple setae. Also, all setae of the body are simple; setae H and K wide apart, K much nearer to L and M than to H on segment I. Paddles narrow and deeply notched at the tip, without setae; both lateral and medial margins with small denticles.

Subgenus *COQUILLETIDIA* Dyar

Fig. 20

**DIAGNOSIS.**—Trumpet long, mainly cylindrical, but the meatus narrowed for a short distance before base of pinna, and with a line of weakness at this point, so that the pinna can very readily be broken off; meatus tracheoid for the greater part of its length; pinna entire, with numerous ridges which presumably serve to hold it firmly in the plant root after insertion. Abdomen shagreened with minute points, except on more or less circular areas occupying the middle one-third of each tergite, these areas being practically smooth but outlined with an irregular series of fine wrinkles; on the posterior margins of the tergites the points are a little larger and produce a finely serrated edge. All the abdominal setae, including A, B, and C, minute, pale, and often difficult to find.

*Mansonia (Coquillettia) xanthogaster*  
(Edwards) 1924

Fig. 21

The pupa has not been described, but Taylor (1944: 126) published figures of the paddles and trumpet of specimens from Cairns, Australia. The figure of the paddles has been redrawn and included here.

Subgenus *MANSONIOIDES* Theobald

**DIAGNOSIS.**—Trumpets differing from those of *Coquillettia* in having the meatus tracheoid for only about one-half its length, and very little narrowed distally, without any line of

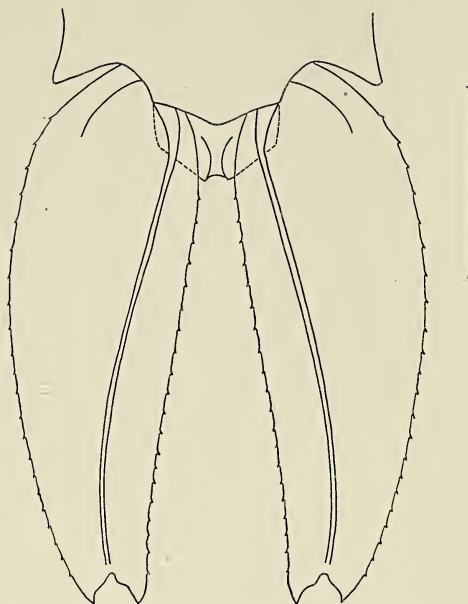


FIG. 21. *Mansonia xanthogaster*: dorsal aspect of terminal abdominal segment and paddles (after Taylor, 1944).

weakness separating it from the pinna; pinna deeply divided into two parts, one pale and very delicately feathered, the other strongly sclerotized and almost spine-like, though feathered on one side. Abdomen with the basal part of each tergite coarsely reticulate, without shagreen, posterior margin prominent but smooth. Setae C-II, C-III, B, and C-IV-VII forming long, stout, dark bristles extending to or beyond posterior margin of the following segments; remaining setae small and obscure as in *Coquillettia*. Paddles about twice as long as broad.

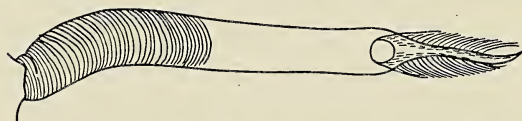


FIG. 22. *Mansonia africana*: pupal trumpet (after Edwards, 1941).

*Mansonia (Mansonioides) africana*  
(Theobald) 1901

Figs. 22, 23

Photographs of the whole pupa in lateral view and notes on its habits were given by Connal (1928: 293) and figures of the whole

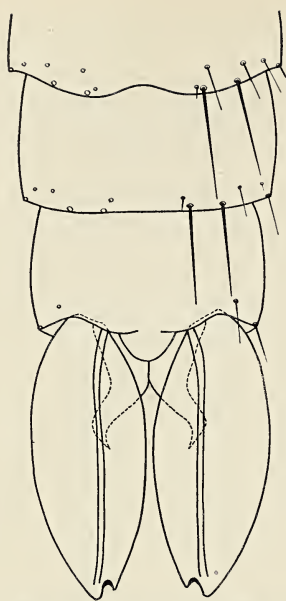


FIG. 23. *Mansonia africana*: dorsal aspect of terminal abdominal segments of male (after Edwards, 1941).

abdomen and paddles in dorsal view and of the trumpets were given by Edwards (1941: 384). The latter reference is the source of the figures and notes included here.

Since all the setae are simple and no other species of the subgenus except *M. uniformis* from New Guinea have been described, it seems unnecessary to attempt a complete and detailed description at this time. According to Edwards the trumpets are long, with the meatus about six times as long as broad.

#### *Mansonia* (*Mansonioides*) *uniformis* (Theobald) 1901

A few notes on the pupa by Edwards and Given (1928: 346) based on specimens from Singapore and without figures are scarcely of diagnostic value. However, Edwards (1941: 384) included a brief note on separating this species from *M. africana*, but no figures.

All that is known may be stated as follows: Abdominal segments II to VII each with four strong setae on the hind margin. Trumpets shorter than in *M. africana*, the terminal chitinized spine of the pinna being about one-third of the total length, its margin smooth; meatus only about four times as long as broad.

#### Genus *AEDOMYIA* Theobald

DIAGNOSIS.—Trumpet short, with large and very oblique opening; a short tracheoid area at base. Cephalothoracic setae mostly small and inconspicuous, but dorsal seta (8) and median metanotal seta (10) large, similar to the float-hair. H, K, L, and M all small and grouped close together; float-hair composed of simple branches, not dendritic, similar to seta C on the following segments. Seta B very long, stout, and dark with some small basal side branches on segments IV to VI. Paddles narrow at base, widened distally, with a long terminal seta; midrib dividing paddle about equally.

#### *Aedomyia catasticta* Knab 1909

Fig. 24

Pupa partially described and fully figured by Baisas (1938: 181) from the Philippine Islands.

DIAGNOSIS.—In addition to the characters of the genus, *A. catasticta* has the following features which distinguish it from the other species. Setae A on segments II–VIII present as a graduated series of stout spines resembling seta A in *Anopheles*; seta v on segment IX is present as a small stout spine as in the genus *Culex*, but much smaller than found in *Uranotaenia*.

DISCUSSION.—Both Baisas (*loc. cit.*) and Edwards (1941: 372) point out that seta B is absent from segments II and III. Realizing that the setae of segment II of most culicines are subject to great variation in position, one might assume that the medium-length stout one mesad of C is B, but this seta conforms in size and form, if not position, to seta C' of the following segments. The only logical conclusion, therefore, is that seta B-II is absent. However, on segment III, if seta B is really absent, there remains a small three- or four-forked seta anterior to and between C' and C to which no designation will be assigned. Therefore, although this seta is not obviously homologous, I am tentatively designating it as B-III.

CEPHALOTHORAX. — *Postocular*: 1 small, simple; 2 small, four-branched; 3 small, four-branched.



*Anterothoracic*: 4 small, simple or two-forked; 5 small, four- or five-forked; 6 small, two- or three-forked; 7 small, simple.

*Dorsal*: 8 medium, similar to float-hair, eight- or nine-branched.

*Supra-alar*: 9 small, simple or two-forked.

*Metanotum*: 10 medium, similar to float-hair, twelve- to fourteen-branched; 11 medium, simple; 12 medium, four-forked.

*Trumpet*: Medium-long, length about four and one-half times greatest diameter of meatus; pinna long, about one-third of total length; tracheoid area darkly pigmented, restricted to basal one-fifth of trumpet.

**ABDOMEN.**—*Segment I*: H very small, simple; K very small, simple; L very small, two- to four-forked; M very small, four-branched; S medium, three- to five-branched; T medium, simple or two-forked; U medium, two-branched; float-hair medium, nine- to fourteen-branched, not dendritic.

*Segment II*: A small, simple spine; B absent; C medium, ten- or eleven-branched; C' medium, simple spine; 1 medium, simple or occasionally four-branched; 2 medium, four- to seven-branched; 3 small, simple or two-forked near apex; 4 medium, six- or seven-branched; 5 small, simple.

*Segment III*: A medium, stout simple spine, exactly on the postero-lateral corner of the segment; B (?) small, three- or four-forked near middle; C medium, ten- to fifteen-branched; C' medium, stout simple spine; 1 medium, five- to seven-branched; 2 small, simple to three-branched; 3 represented only by its socket; 4 medium, six-branched; 5 minute, simple on this and all following segments.

*Segment IV*: A similar to A-III; B long, stout, with a few short simple branches near base, otherwise plumose and simple; C long, a little less than half of B, seven- to nine-branched; C' smaller than C'-III, stout, simple spine on this and all following segments; 1 medium, seven-branched; 2 small, two-branched or forked; 3 represented only by its socket; 4 small, three- to five-branched.

*Segment V*: A similar to A-IV; B very long,

similar to B-IV; C medium, seven- to nine-branched; 1 medium, six- or seven-branched; 2 small, simple to four-forked; 4 small, simple; 3 represented only by its socket.

*Segment VI*: A similar to A-V; B very long, similar to B-V; C medium, five-branched; 1 medium, three- or four-branched; 2 small, simple; 3 absent; 4 small, simple.

*Segment VII*: A medium, stout, two-branched; B long, about two-thirds length of B-VI, plumose but without basal side branches; C medium, four- or five-branched; 1 very small, four-branched; 2 very small, simple; 4 very small, simple to three-branched.

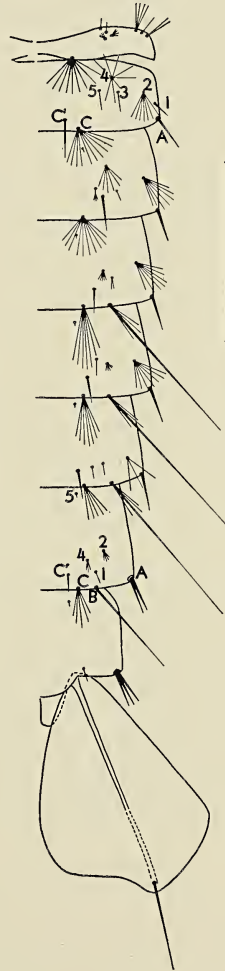


FIG. 24. *Aedomyia catasticta*: dorsal aspect of right half of abdomen of male from Caminawit Point, Mindoro, Philippine Islands.

*Segment VIII*: A medium, stout, three-branched; A' small, simple or two-forked near apex.

*Segment IX*: v small, simple spine.

*Paddle*: Roughly triangular, narrow basally with apex expanded; midrib strong basally, fading at apical one-third into an oval area of light-brown pigment; terminal seta very long, simple, slightly plumose; accessory seta absent.

**SPECIMENS EXAMINED.**—The pupal exuviae of ten males and ten females from Caminawit Point (near San José), Mindoro Island, Philippine Islands, collected by the writer.

### Genus *Aedes* Meigen

**DIAGNOSIS.**—According to Edwards (1941: 384) no single feature has been found which will separate all pupae of *Aedes* from all others, but most species of the genus have the following features in common: Trumpets short, without definite tracheoid portion except in the subgenus *Mucidus*. Float-hairs always well developed and normally dendritic. Seta A on II–VI usually minute; A–VII not forming a conspicuous tuft; A–VII and A–VIII very near to corners of segments. Paddles with terminal seta only, no accessory seta.

It is more satisfactory to treat the species of *Aedes* strictly by subgenera because of the divergences of the genus as a whole.

### Subgenus *MUCIDUS* Theobald

**DIAGNOSIS.**—In New Guinea the two species known in the pupal stage differ markedly in the length of the trumpet, and, in contrast to all other *Aedes*, have a rather definite tracheoid area. Otherwise, except for its large size, the pupal stage of *Mucidus* is not particularly outstanding although the great distance between setae C-II and B-II holds promise of being unique.

### Key to Species of *Aedes* (*Mucidus*)

Trumpet moderately long with straight sides, total length not over five times greatest diameter of meatus; tracheoid area restricted to basal one-fifth of trumpet (Figs. 25, 26).....*A. alternans*

Trumpet about ten times as long as greatest diameter of meatus; tracheoid area occupying at least basal one-third of trumpet (Figs. 27, 28).....*A. aurantius* spp.



FIG. 25. *Aedes alternans*: pupal trumpet of female from Brisbane, Australia.

*Aedes* (*Mucidus*) *alternans* (Westwood)  
1835

Figs. 25, 26

Pupa not described, but figures of the paddles and trumpet of specimens from North Queensland, Australia, were included by Hill (1925: 70). The figures and diagnosis included here are based on a single denuded specimen from Brisbane, Australia, collected by Mr. F. A. Perkins of the University of Queensland.

**DIAGNOSIS.**—Readily separated from *A. aurantius* spp. by the trumpet, which is moderately long with straight sides; total length about five times greatest diameter of the meatus; tracheoid area with almost complete rings,

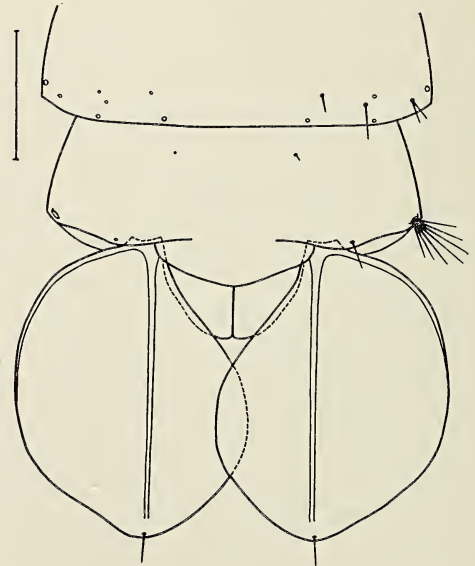


FIG. 26. *Aedes alternans*: dorsal aspect of terminal abdominal segments of female from Brisbane, Australia.



restricted to the basal one-fifth of the trumpet; pinna not flared at apex.

Since the only specimen available for study was almost bare of all setae no attempt was made to describe its chaetotaxy.

***Aedes (Mucidus) aurantius aurantius***  
(Theobald) 1907

Pupa partially described and figures of the trumpet and paddles given by Edwards and Given (1928: 341) from Singapore specimens. The descriptive notes, quoted verbatim below, are too brief to be of value in separating this subspecies from *chrysogaster*.

Respiratory horns about half as long as the thorax; basal third or rather more blackish, as is the expanded tip, the rest pale and rather more slender. A small three-branched tuft behind the horn. First abdominal segment with a pair of large tufts; 2-7 with long single sub-lateral hairs, the other hairs inconspicuous; 8 with small 4-branched apical lateral tufts. Paddles rounded, without fringe; a small simple apical bristle; midrib strong.

***Aedes (Mucidus) aurantius chrysogaster***  
(Taylor) 1927

Figs. 27, 28

**DIAGNOSIS.**—The long trumpets, which are about ten times as long as their greatest diameter; the long tracheoid area, which is about one-third of the total length of the trumpet; and the position of seta C-II, which is removed from B-II by a distance nearly equal to the length of the segment, should readily distinguish this species from all other *Aedes*.

**CEPHALOTHORAX.**—*Postocular*: 1 medium, two- or three-forked; 2 medium, two-forked or occasionally simple or three-forked; 3 medium, simple to four-forked.

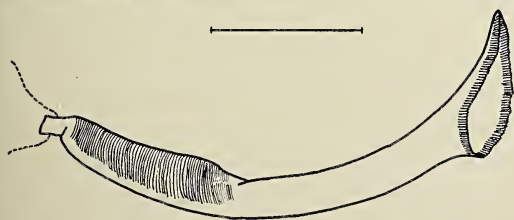


FIG. 27. *Aedes aurantius chrysogaster*: pupal trumpet of male from Aoeki Island, Dutch New Guinea.

*Anterothoracic*: 4 medium, usually four-forked, may be simple or two-forked; 5 medium, simple to five-forked; 6 minute, two- to six-branched; 7 medium, simple to three-forked.

*Dorsal*: 8 very long, almost equal to length of trumpets and placed almost between them, two-branched or simple.

*Supra-alar*: 9 small, three- to six-forked.

*Metanotum*: 10 small, usually five-branched, rarely six-branched; 11 medium, three- to six-forked near base; 12 medium, usually three-forked near apex, range from three to seven. *Trumpet*: Long, narrow, length about ten times the greatest diameter of meatus; pinna expanded, less than one-twelfth of the total length; tracheoid area with nearly complete rings and occupying about one-third of the total length of the trumpet; tracheoid and pinna dark pigmented, the rest pale.

**ABDOMEN.**—*Segment I*: H very small, two-forked; K long, two- or three-branched; L very small, four- to six-forked near middle; M very small, seven- to ten-branched; S long, simple; T long, slightly shorter than S, four-branched; U minute, simple.

*Segment II*: A small, simple spine; B small, four-forked near middle; C very large, black, three- or four-branched from proximal one-third; C' very small, simple; 1 long, five-forked from near base; 2 very long, simple; 3 long, four-forked from near base; 4 very small, two-branched with each branch apically three-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B small, four-forked near base; C long, three-branched; C' very small, simple on this and all following segments; 1 long, simple or two-forked; 2 very small, four- to six-forked; 3 represented only by its socket; 4 small, six- or seven-branched.

*Segment IV*: A small, simple spine; B very long, simple; C long, two-branched; 1 long, two-forked; 2 very small, two- to four-forked; 3 represented only by its socket; 4 very small, six-forked from near base.

*Segment V*: A small, simple spine; B very long, reaching posterior margin of VII, simple; C

long, simple or two-branched; C' very small, simple or two-forked near apex; 1 long, simple or three-forked near apex; 2 very small, five- to seven-forked near base; 3 represented only by its socket; 4 long, two- or three-forked near base.

*Segment VI*: A small, simple spine; B very long, simple; C long, two- or three-branched; 1 long, simple, well removed from lateral margin; 2 long, three- or four-forked near base; 4 long, two-branched.

*Segment VII*: A medium length, stout, two-branched, plumose; B very small, three-forked near base; C long, simple; 1 very small, two-branched, each branch two- or three-forked near

apex; 2 long, simple or two-forked near apex; 4 long, simple.

*Segment VIII*: A medium length, stout, plumose, three- or four-branched, each branch forked near apex; A' longer than A, two-forked near base.

*Paddle*: Roughly oval-shaped, margin smooth for the most part, but with very fine inconspicuous serrations near apex; terminal seta small, simple; midrib strong, not reaching apex, dividing the paddle unequally, the lateral face a little wider than medial face.

**SPECIMENS EXAMINED**.—One pupal exuvium and two pupae of males from Aoeki Island, Dutch New Guinea, collected by Dr. Arthur G. Humes.

#### Subgenus *OCHLEROTATUS* Lynch-Arribalzaga

The pupa of only one species of this subgenus has been described in detail, hence the preparation of a diagnosis of *Ochlerotatus* must wait for further study, especially of the numerous North American species. From what little is known about them it is probable that species of this subgenus will key down to the subgenus *Aedes*.

#### *Aedes (Ochlerotatus) vigilax* (Skuse) 1889

Fig. 29

Pupa undescribed, but Hill (1925: 71) included figures of the posterior margin of segment VIII, the paddles, and trumpet which have been redrawn and included here. Cooling (1924: 19) included a few notes on the pupae but gave nothing which is of any diagnostic value.

#### Subgenus *FINLAYA* Theobald

**DIAGNOSIS**.—The eight species which are described in this paper have the following features in common. Seta H small, K much longer and stronger, subequal to or longer than S and T. Seta 2 on segment II long, various in its length relations to B-II; C-II not more than six-branched, each branch simple, medium length; B and C on III rather close together, B anterior to C in some species. Paddle with margin either smooth or finely serrate, never with a fringe of fine hairs.

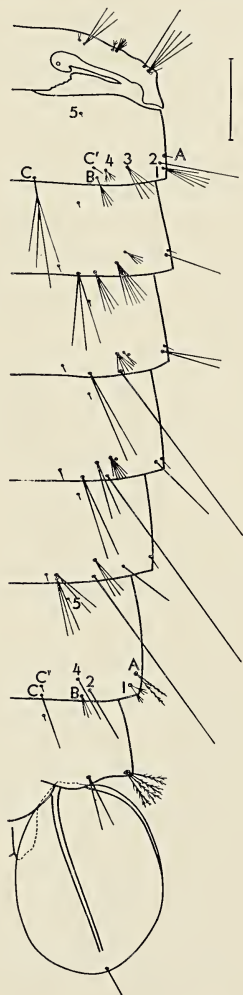
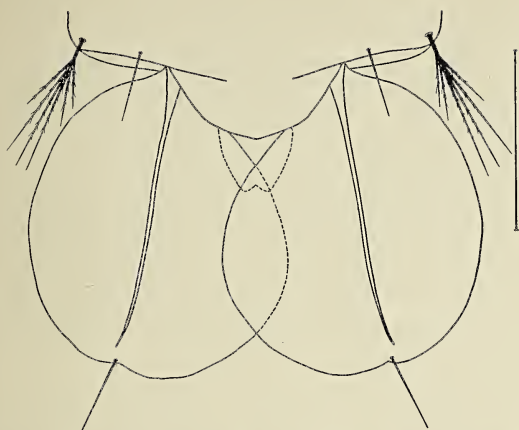


FIG. 28. *Aedes aurantius chrysogaster*: dorsal aspect of right half of abdomen of male from Aoeki Island, Dutch New Guinea.



FIG. 29. *Aedes vigilax*: paddles (after Hill, 1925).Key to Species of *Aedes* (Finlaya)

1. Paddles with serrate margins.....2  
Paddles with smooth margins.....5
2. Seta A-VIII with no more than five stout branches; seta C-II two- to six-branched..3  
Seta A-VIII normally a tuft of more than seven branches; seta C-II simple.....4
3. Seta B exceeding the posterior margin of the following segment on segments IV-V only; paddles rounded apically with a notch at tip of midrib (Fig. 30).....*A. notoscriptus*  
Seta B exceeding the posterior margin of the following segment on segments III through VI; paddles more or less pointed apically, never notched (Fig. 31).....*A. keefeii*
4. Seta 2 on segment II very long, longer than B-II; paddles long and narrow, rounded apically; setae B-IV-VI slightly plumose apically (Fig. 32).....*A. wallacei*  
Seta 2 on segment II medium, not longer than B-II; paddles shorter and more rounded, apex with a notch at end of midrib; setae B-IV-VI not plumose (Fig. 33).....*A. kochi*
5. Seta B exceeding posterior margin of following segment on segments IV and V only; dorsal seta (8) of cephalothorax large, dendritic (Fig. 34).....*A. candidoscutellum*  
Seta B exceeding posterior margin of following segment on at least segments IV, V, and VI; dorsal seta of cephalothorax medium or large but not dendritic .....6

6. Seta A-VIII with six to eleven stout, simple, plumose branches (Fig. 35).....*A. papuensis*  
Seta A-VIII with five to ten stout branches, each branch two- or four-branched apically (dendritic).....7
7. Seta C-II with four to eight branches; seta C-III with four to six branches; setae B-III-VI not plumose apically (Fig. 36).....*A. hollandius*  
Seta C-II with two to five branches; seta C-III with two to four branches; setae B-III-VI slightly plumose apically (Fig. 37).....*A. novalbitarsis*

*Aedes* (Finlaya) *notoscriptus* (Skuse) 1889  
Fig. 30

Pupa undescribed by Hill (1925: 72), who included figures of the paddles and trumpet, but Graham (1929: 205) included a description and figures of specimens from New Zealand.

CEPHALOTHORAX.—*Postocular*: 1 long, simple or occasionally two-forked near middle; 2 long, simple; 3 long, simple.

*Anteröthoracic*: 4 medium, simple or two-forked; 5 long, simple; 6 small, simple or rarely two-forked near apex; 7 long, two-forked near middle or simple.

*Dorsal*: 8 long, three-fourths length of trumpet, simple or two- to three-forked.

*Supra-alar*: 9 medium, simple.

*Metanotum*: 10 long, thin, two-forked or simple; 11 long, stout, simple; 12 long, thin, simple.

*Trumpet*: Funnel-shaped, length roughly three times the greatest diameter of meatus; pinna about one-third of total length; uniformly dark-pigmented.

ABDOMEN.—*Segment I*: H small, stout, simple; K long, simple; L small, two- or three-forked near apex, rarely simple; M medium, two- or three-forked near basal third; S long, simple; T long, simple; U small, simple.

*Segment II*: A small, simple spine; B long, simple; C medium, three- to six-branched, rarely more; C' small, simple spine on this and all following segments; 1 medium, simple or rarely two-forked; 2 long, simple; 3 medium, simple or rarely two-forked at apex; 4 small, three- or two-forked near middle, rarely four- or five-

forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple; C medium, simple or occasionally two- or three-forked; 1 medium, simple or rarely two-forked near apex; 2 small, two-forked or occasionally three-forked or simple; 3 represented only by its socket; 4 medium, simple.

*Segment IV*: A small, simple spine; B very long, stout, simple; C long, simple or two-forked; 1 medium, simple or rarely two-forked near apex; 2 small, simple or two-forked; 3 represented only by its socket; 4 medium, three- or two-forked.

*Segment V*: A small, simple spine; B very long,

stout, simple; C long, simple or occasionally two-forked; 1 long, simple or rarely two-forked; 2 small, usually three-forked near middle, occasionally two- or four-forked or simple; 3 represented only by its socket; 4 long, simple or two-forked near apex.

*Segment VI*: A small, simple spine; B long, simple; C medium, simple or occasionally two-forked; 1 long, simple or occasionally two-forked; 2 medium, usually two-forked, occasionally simple or three-forked; 3 absent; 4 medium, simple.

*Segment VII*: A medium, stout, plumose, two-branched or rarely three-forked near base; B medium, simple; C medium, simple or rarely two-forked; 1 medium, stout, plumose, usually two-branched, occasionally simple or three-branched; 2 medium, simple; 4 medium, simple or rarely two-forked.

*Segment VIII*: A long, stout, plumose, three- to five-branched; A' medium, simple.

*Paddle*: Roughly oval, a little longer than wide, with a notch at the end of the midrib; margin serrate around apical half excepting the notch; midrib strong, dividing the paddle almost equally, but medial face slightly wider than lateral face; terminal seta medium, simple; one specimen with an irregular line of black pigment across the base of one paddle, all others non-pigmented.

**SPECIMENS EXAMINED.**—The pupal exuviae of nine males and fifteen females from Gama-dodo, WagaWaga, and Hilimoi, Milne Bay, Papua; Draeger Harbor, Northeast New Guinea; and Amsterdam Island, Dutch New Guinea.

*Aedes* (Finlaya) keepei King and Hoogstraal 1946

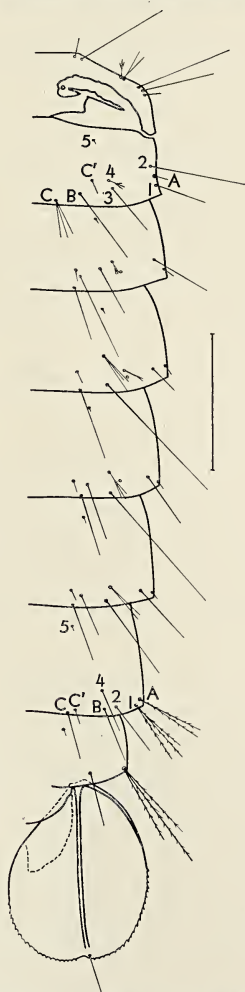


FIG. 30. *Aedes notoscriptus*: dorsal aspect of right half of abdomen of male from Draeger Harbor, Northeast New Guinea.

Fig. 31

**DIAGNOSIS.**—Differing from all other New Guinean species of *Finlaya*, except perhaps *quasirubrithorax*, in having the paddles distinctly produced into an apical point.

**CEPHALOTHORAX.**—*Postocular*: 1 long, two- to four-forked; 2 long, simple or two-forked, rarely three-forked; 3 long, two-forked or occasionally three-forked.



*Anterothoracic*: 4 medium, two- or three-forked near base; 5 long, two-forked near base; 6 small, two- or three-forked near base, rarely four-forked; 7 very long, exceeding length of trumpet, two- or three-forked near base.

*Dorsal*: 8 long, about three-fourths length of trumpet, three- or four-forked or branched.

*Supra-alar*: 9 long, two-forked near base, rarely simple.

*Metanotum*: 10 medium, seven- to eleven-branched; 11 long, simple; 12 medium, four- or five-forked near base.

*Trumpet*: Funnel-shaped, length usually about four times the greatest diameter of the meatus; pinna long, a little less than one-third of total length; uniformly dark pigmented.

**ABDOMEN.**—*Segment I*: H small, simple; K long, simple or two-branched; L small, simple; M medium, three- to five-branched; S very long, simple; T long, two-forked near base, or rarely simple; U small, simple.

*Segment II*: A small, simple; B long, simple; C long, two- to four-branched; C' small, simple on this and all following segments; 1 medium, two- or three-forked near base, rarely simple; 2 very long, simple; 3 medium, five- or six-branched, rarely more; 4 small, three- to seven-branched; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple; B very long, simple; C long, three-branched or occasionally five- or six-branched; 1 medium, three-branched or rarely four-branched; 2 small, two- or three-forked near middle, or simple; 3 represented only by its socket; 4 medium, four-branched, occasionally five- or six-branched.

*Segment IV*: A small, simple; B very long, almost reaching posterior margin of segment VI, simple; C long, two- or three-branched, rarely five-branched; 1 medium, three- or four-branched, rarely five-branched; 2 small, simple; 3 represented only by its socket; 4 medium, four- or three-branched.

*Segment V*: A small, simple; B very long, almost reaching posterior margin of segment VII, simple; C long, two-branched, or occasionally three- or four-branched; 1 medium, two-branched or

occasionally three- or four-branched; 2 small, five- or six-branched, or less frequently three- to eight-branched; 3 represented only by its socket; 4 medium, simple or two-forked near middle.

*Segment VI*: A small, simple; B very long, exceeding the posterior margin of segment VII, simple; C long, simple or two-branched; 1 medium, two-branched or rarely three-branched; 2 medium, usually two-forked, occasionally three-forked; 3 absent; 4 medium, usually simple, occasionally three-forked near apex.

*Segment VII*: A medium, two-branched or rarely three-branched; B long, simple; C long, simple or rarely two-forked; 1 small, various, range

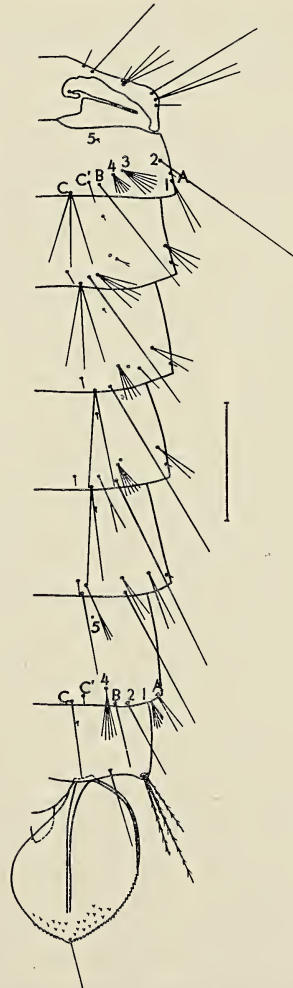


FIG. 31. *Aedes keefeii*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

from three- to six-forked; 2 long, simple or two-forked; 4 medium, two- or three-forked, rarely five-forked near basal third.

*Segment VIII*: A very long, stout, plumose, three- to five-branched; A' long, simple or occasionally two-forked near apex.

*Paddle*: Elongate oval, pointed apically; margin finely serrate laterally from about middle around apex; apical dorsal face with a number of distinct fine spinules; midrib strong, ending before apex, dividing the paddle almost equally or with lateral face slightly wider than medial; terminal seta long, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of four males and six females from Hilimoi, Milne Bay, Papua.

*Aedes* (Finlaya) *quasirubrithorax*  
(Theobald) 1918

This pupa is undescribed, but Hill (1925: 72) included figures of the paddles and trumpet of specimens from Townsville, Australia. They show similarities to those of *A. keefeii*, but are not included here since there is some doubt as to the correctness of Hill's identification.

*Aedes* (Finlaya) *wallacei* Edwards 1926  
Fig. 32

**CEPHALOTHORAX**.—*Postocular*: 1 medium, simple or two-forked; 2 medium, two-forked near base; 3 very long, two-branched.

*Anterothoracic*: 4 medium, two- to five-forked near base; 5 medium, two-forked; 6 small, simple or two- to three-forked; 7 medium, simple or two- to three-forked.

*Dorsal*: 8 medium, simple or three- to four-forked.

*Supra-alar*: 9 medium, simple or two- to three-forked.

*Metanotum*: 10 small, usually four- or five-forked; 11 long, stout, simple; 12 long, usually six-forked, or occasionally three- to five-forked.

*Trumpet*: Short, funnel-shaped; lightly pigmented except for the obsolete tracheoid portion which is dark; length about three times greatest diameter of meatus; pinna short, less than one-third of length of trumpet.

**ABDOMEN**.—*Segment I*: H small, simple or two-forked; K long, simple; L small, simple; M small, two- to four-forked near base; S very long, simple; T long, two- or three-forked; U very small, simple.

*Segment II*: A small, simple spine; B long, simple; C small, simple; C' small, simple on this and all following segments; 1 medium, simple or two-forked near apex; 2 very long, simple or two-forked near middle; 3 small, two- or three-forked near middle; 4 small, simple or two- to three-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B very long, simple, plumose apically; C medium, two-forked near base; 1 medium, simple; 2 small, simple

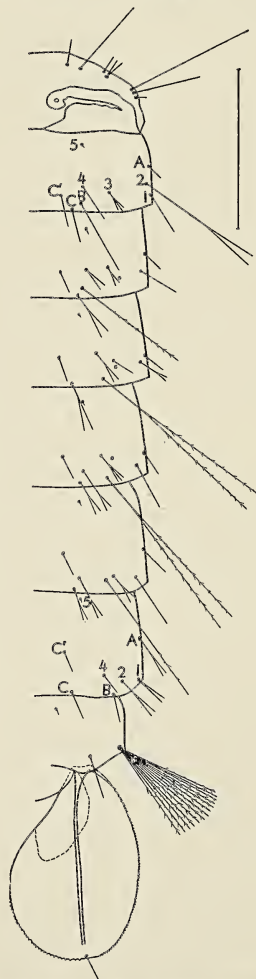


FIG. 32. *Aedes wallacei*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.



or two-forked; 3 represented only by its socket; 4 small, two- or three-forked near base.

*Segment IV*: A small, simple spine; B very long, reaching to middle of segment VI, two-forked near basal one-third, plumose apically; C medium, two- or three-forked near base; 1 small, simple or two-forked near apex; 2 small, simple; 3 represented only by its socket; 4 small, two- or three-forked near apex.

*Segment V*: A small, simple spine; B very long, equal to B-IV in length, two-forked near basal one-third, plumose apically; C medium, two- or three-forked near middle; 1 medium, simple or two-forked; 2 small, three- or four-forked near middle; 3 represented only by its socket; 4 medium, two-forked near apex.

*Segment VI*: A small, simple spine; B very long, but shorter than B-V, simple or two-forked at apex, plumose apically; C small, two-forked near apex; 1 medium, simple; 2 small, two- or three-forked near middle; 3 absent; 4 medium, two-forked apically or simple.

*Segment VII*: A medium length, two- or three-forked apically; B small, simple or two- to three-forked; C small, simple; 1 small, simple or two- to three-forked near middle; 2 medium, simple or two-forked near middle; 4 small, simple.

*Segment VIII*: A long, large, conspicuous, plumose, eleven- to fifteen-branched tuft, most often thirteen-branched; A' medium, simple.

*Paddle*: Elongate oval; margin very finely serrate from extremity of buttress around to middle of medial margin; midrib strong, not reaching apex, dividing paddle almost equally; pigment present on only one specimen which had a small spot of black near the base of each paddle; terminal seta small, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of two males and three females from Hilimoi, Milne Bay, Papua.

### *Aedes (Finlaya) kochi* (Dönitz) 1901

Fig. 33

Pupa partially described by Brug (1932: 22), who included figures of the trumpet and paddles as *A. poicilia*, and completely described and figured by Marks (1947a: 16).

**DIAGNOSIS**.—Distinct in having the paddle serrate and apically notched and most of the smaller abdominal setae simple.

**CEPHALOTHORAX**.—*Postocular*: 1 medium, two- or three-forked; 2 medium, two- to four-forked; 3 very long, two-branched.

*Anterothoracic*: 4 medium, two-forked; 5 medium, two-forked usually but eight-forked on one side of one of the specimens examined; 6 medium, two- or three-forked; 7 medium, two- to four-forked.

*Dorsal*: 8 medium, equal to greatest diameter of trumpet, two-forked.

*Supra-alar*: 9 medium, usually simple, occasionally two- or three-forked.

*Metanotum*: 10 long, two-forked; 11 long, simple, occasionally slightly plumose; 12 long, usually five-forked near base, occasionally two- or three-forked.

*Trumpet*: Funnel-shaped, length about three times the greatest diameter of meatus; pinna equal to about one-third of total length; tracheoid portion darker than rest.

*Pigmentation*: Abdominal segment I darkly pigmented overall, extending posteriorly, but lighter, to the center of segments II and III. Metanotum darkly pigmented overall, extending anteriorly onto dorsal thorax but fading before reaching trumpets.

**ABDOMEN**.—*Segment I*: H small, simple; K long, simple; L small, usually simple or occasionally two-, four-, or five-forked; M small, two- to five-forked near middle; s long, usually simple, rarely three-forked near base; T long, two-forked near middle or simple; U small, simple.

*Segment II*: A small, simple spine; B long, simple; C small, simple, rarely three-branched; C' small, stout, simple on this and all following segments; 1 medium, usually simple or occasionally two- or three-forked; 2 medium, usually simple, occasionally two- or three-forked; 3 small, three- or four-forked, occasionally simple or two-forked near base; 4 medium, two- or three-forked near base, occasionally simple; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B long, simple; C small, simple or two- to three-forked; 1 medium, simple; 2 small, two- or three-forked near middle, rarely simple; 3 represented only by its socket on this and segments IV and V; 4 medium, two- or three-forked just below middle.

*Segment IV:* A small, simple spine; B very long, two-branched; C small, simple or two-forked, rarely more; 1 small, usually simple, rarely two-forked near base; 2 small, simple or two-forked; 4 medium, two- or three-forked just below middle.

*Segment V:* A small, simple spine; B very long, two-branched; C medium, simple or two-forked;

1 small, usually simple; 2 small, two- to four-forked, occasionally simple or five-forked; 4 medium, simple or two-forked.

*Segment VI:* A small, simple spine; B very long, two-forked near basal fourth; C small, simple or two-forked; 1 long, usually simple, occasionally two-forked; 2 small, simple or two-forked; 3 absent; 4 small, usually two-forked near base, rarely simple.

*Segment VII:* A long, two- to five-branched, usually four-branched; B small, usually simple, occasionally two- to four-forked; C small, simple or two-forked; 1 small, simple or two-forked, greatly displaced, being far anterior to its normal position; 2 small, simple or two-forked; 4 small, usually simple, occasionally two-forked.

*Segment VIII:* A large, conspicuous, plumose, seven- to fifteen-branched, usually ten-branched; A' medium, usually simple, occasionally two-forked near apex.

*Paddle:* Rounded laterally, apex deeply notched; widest near apical one-third; margin finely serrate laterally, coarser medially to widest point; midrib strong, does not reach apical notch, divides paddle more or less equally, the medial face slightly wider than lateral face; terminal seta medium, simple, rarely two-forked apically.

**SPECIMENS EXAMINED.**—The pupal exuviae of thirteen males and seven females from Hilimoi, Milne Bay, Papua, and Amsterdam Island, Dutch New Guinea.

*Aedes (Finlaya) candidoscutellum* Marks 1947

Fig. 34

This pupa was partially described and figured by Marks (1947b: 8).

**DIAGNOSIS.**—Apparently distinct from other New Guinea *Finlaya* in having the dorsal seta (8) of the cephalothorax a well-developed dendritic tuft.

**CEPHALOTHORAX.** — *Postocular:* 1 small, four- or five-forked; 2 long, two-forked; 3 medium, three-forked.

*Anterothoracic:* 4 long, three-forked; 5 long, two- or three-forked; 6 small, two- or three-forked, or simple; 7 long, two- or three-forked.

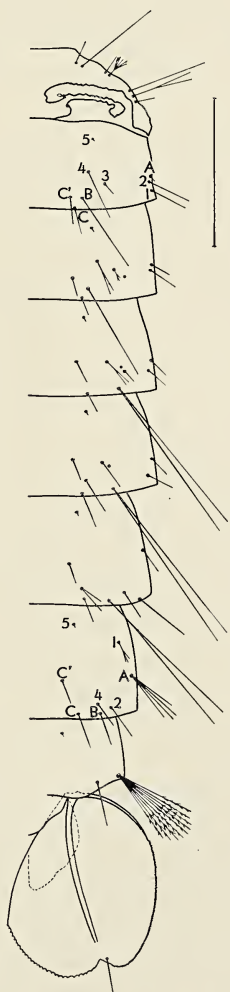


FIG. 33. *Aedes kochi*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.



*Dorsal*: 8 large, dendritic, basally four-branched, each branch further branched two to four times, the number of ultimate branches thus ranging from eleven to seventeen.

*Supra-alar*: 9 medium, slightly plumose on some specimens, three- to five-forked near base.

*Metanotum*: 10 short, three- to nine-forked near base; 11 long, simple; 12 medium, five- or six-forked near base.

*Trumpet*: Short, inflated near middle so that opening of pinna is less than the greatest diameter of the meatus; the tracheoid portion practically obsolete; uniformly black-pigmented.

**ABDOMEN.**—*Segment I*: H small, simple; K long, simple or three-forked near apex; L small, simple or two-forked; M medium, three- to five-branched; S long, simple; T long, two-forked near apex; U very small, simple.

*Segment II*: A small, simple spine; B medium, simple; C long, six-branched; C' small, simple on this and all following segments; 1 medium, usually two-forked, or occasionally simple or three-forked; 2 long, simple or two-forked near apex; 3 medium, four- to six-forked near base; 4 small, three- to six-forked near base; 5 very small, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple; C long, four- to seven-branched; 1 medium, two-branched, each branch two- or three-forked near apex; 2 small, with two to four branches on one side only; 3 represented only by its socket; 4 medium, four- to six-branched.

*Segment IV*: A small, simple spine; B very long, reaching posterior margin of segment VI, simple; C medium, three- or four-branched; 1 similar to 1-III; 2 small, simple or two-forked; 3 represented only by its socket; 4 small, two- to five-forked near base.

*Segment V*: A small, simple spine; B very long, reaching posterior margin of segment VII, simple; C medium, two- or three-branched or forked near base; 1 small, two- to four-forked near base; 2 small, similar to 2-III; 3 represented only by its socket; 4 medium, two-forked near apex.

*Segment VI*: A small, simple spine; B medium, simple or two-forked near apex; C longer than

B, simple or two-forked near apex; 1 small, simple or two-forked near apex; 2 small, similar to 2-III; 3 absent; 4 medium, two-forked near middle, or simple.

*Segment VII*: A small, slightly plumose, usually two-branched, may be three- or four-branched; B small, simple or two-forked near base; C medium, simple or two-forked near apex; 1 small, three-forked near base or simple; 2 medium, two-forked near base; 4 small, two- to four-forked near base.

*Segment VIII*: A medium, plumose, three- to eight-branched, usually seven- or eight-branched; A' medium, two-forked near apex or simple.

*Paddle*: Rounded, length barely exceeding greatest width; margin mostly smooth, but very

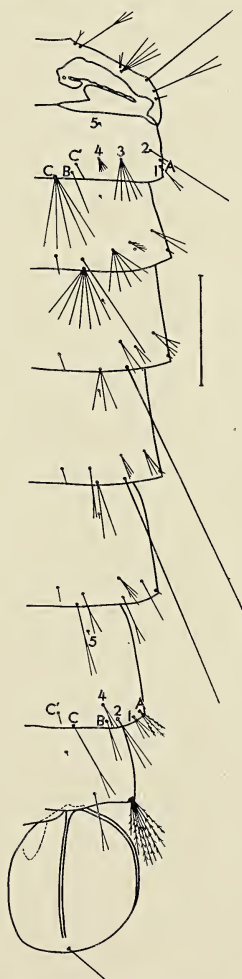


FIG. 34. *Aedes candidoscutellum*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

finely toothed near apex on some specimens; midrib strong, dividing paddle almost equally but lateral face may be slightly wider than medial face; terminal seta medium, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of two males and one female from Hilimoi, Milne Bay, Papua.

*Aedes* (Finlaya) *papuensis* (Taylor) 1914

Fig. 35

**CEPHALOTHORAX.**—*Postocular*: 1 small, two- or three-forked near base; 2 medium, two-forked near base; 3 small, two- or three-forked basally.

*Anterothoracic*: 4 medium, three- or four-forked near base, rarely two- or five-forked; 5 medium, two- to four-forked; 6 small, simple or two- to three-forked near base; 7 medium, two-forked near base or rarely three-forked.

*Dorsal*: 8 long, about three-fifths length of trumpet, usually two-forked near base, less often three-forked or simple.

*Supra-alar*: 9 long, simple or infrequently two-forked near base.

*Metanotum*: 10 long, two- to five-forked near base; 11 long, simple; 12 medium, usually two- or three-forked, rarely simple or four-forked.

*Trumpet*: Short, funnel-shaped, the length being about two and one-half times greatest diameter of meatus; pinna long, slightly less than one-half the length of the trumpet; uniformly dark-pigmented.

**ABDOMEN.**—*Segment I*: H small, simple or rarely two-forked; K long, simple or two-forked, rarely slightly plumose; L small, usually two-forked near base or occasionally three- or four-forked; M small, three- to six-forked near base; S medium, simple or rarely two-forked; T medium, usually two-forked near base, rarely simple or three-forked; U small, simple.

*Segment II*: A small, simple spine; B long, simple, stout; C medium, two- or three-branched, rarely simple or four-branched; C' small, simple on this and all following segments; 1 medium, simple or two- to three-forked, rarely four-forked; 2 medium, simple or rarely two-forked; 3 medium, simple or two-forked; 4 small, two-

to five-branched; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, reaching to posterior margin of segment IV, simple; C medium, simple or two-branched; 1 medium, two-forked or simple; 2 small, two- or three-forked near base, rarely simple; 3 represented only by its socket; 4 medium, simple or two-forked.

*Segment IV*: A small, simple spine; B long, simple or rarely two-branched; C medium, two-branched or rarely simple; 1 medium, simple or two- to three-forked near apex; 2 small, two-forked near base or simple; 3 represented only by its socket; 4 small, two- or three-forked near base, rarely simple.

*Segment V*: A small, simple spine; B long, simple; C medium, two-forked near base or simple; 1 medium, simple or two-forked; 2 small, two- to five-forked; 3 represented only by its socket; 4 medium, two-forked or rarely simple.

*Segment VI*: A small, simple spine; B long, simple; C small, two-forked or simple; 1 medium, simple; 2 small, two- to four-forked near base or simple; 3 absent; 4 small, simple or rarely two-forked.

*Segment VII*: A medium length, stout, plumose, four- to six-branched, rarely two-branched; B medium, simple or rarely two- to three-forked near apex; C small, two-forked or simple; 1 medium, similar to A and subequal to it, plumose, three- to six-branched, rarely two-branched; 2 medium, simple or two-forked; 4 small, simple or two-forked.

*Segment VIII*: A medium length, stout, plumose, six- to eleven-branched, usually nine-branched; A' medium, simple.

*Paddle*: Almost round, width usually slightly exceeding the length, apex rounded and appearing sometimes as a more or less blunt edge; margin sometimes very finely toothed laterally, smooth medially; midrib not strong, dividing paddle unequally, the lateral face being somewhat wider than medial face; terminal seta medium length, simple or rarely two-forked near basal one-fourth.



**SPECIMENS EXAMINED.**—The pupal exuviae of thirteen males and seventeen females from Gamadodo, WagaWaga, Hilimoi, and Kana-Kope, Milne Bay, Papua.

*Aedes* (Finlaya) *hollandius* King and Hoogstraal 1946

Fig. 36

**DIAGNOSIS.**—Very difficult to separate from *A. novalbitarsis* but apparently distinct from all other species of *Finlaya* in the character of seta A-VIII, which is dendritically branched.

**CEPHALOTHORAX.** — *Postocular*: 1 small, usually two-forked, occasionally three- to five-forked; 2 long, two-forked; 3 long, two-forked or simple.

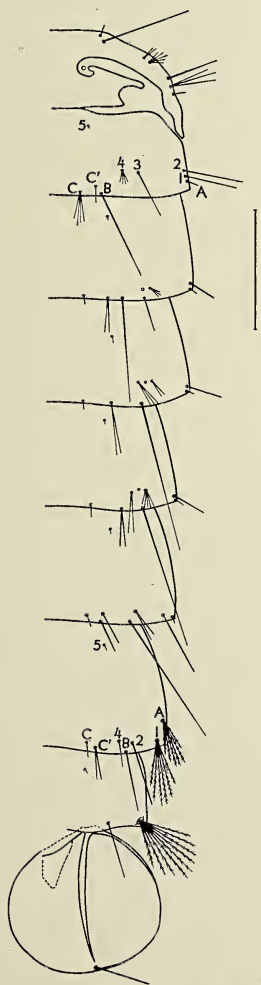


FIG. 35. *Aedes papuensis*: dorsal aspect of right half of abdomen of female from WagaWaga, Papua.

*Anterotheracic*: 4 small, two- or three-forked, rarely simple; 5 medium, two-forked; 6 very small, usually simple, occasionally two- or three-forked near apex; 7 long, two- or three-forked.

*Dorsal*: 8 long, about one-half length of the trumpet, two- or three-forked, rarely simple.

*Supra-alar*: 9 medium, two- or three-forked, rarely simple.

*Metanotum*: 10 medium, two- or three-forked near base, rarely simple; 11 long, simple; 12 medium, three- or four-forked, rarely two- or five-forked.

*Trumpet*: Funnel-shaped, length about four times greatest diameter of meatus; pinna long, about one-third of total length; uniformly dark-pigmented.

**ABDOMEN.**—*Segment I*: H small, stout, simple; K long, stout, simple; L small, usually simple, occasionally two- or three-forked near apex; M small, usually four-forked near middle, occasionally three- or five-forked; S long, simple; T long, usually two-forked near basal one-fourth, rarely simple; U small, simple.

*Segment II*: A small, simple spine; B very long, stout, simple; C long, usually five-branched, range from four- to eight-branched; C' small, simple spine on this and all following segments; 1 long, three- or four-forked near base, rarely two-forked; 2 long, usually simple, occasionally two-forked; 3 medium, usually three-forked near base, range from simple to five-forked; 4 small, two- to five-forked near base, usually four-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B very long, stout, simple; C long, four- or five-branched, rarely six; 1 medium, three- or four-forked near basal one-fourth, occasionally simple or two-forked; 2 small, two- or three-forked near middle; 3 represented only by its socket; 4 medium, three- or four-forked, rarely five-forked.

*Segment IV*: A small, simple spine; B very long, stout, simple; C long, three- or four-branched, occasionally two-branched; 1 medium, three- or four-forked near basal one-fourth; 2 small, two- to four-forked near middle; 3 represented only

by its socket; 4 long, three- to six-forked near base.

*Segment V*: A small, simple spine; B very long, stout, simple; C medium, two- or three-forked near base; 1 medium, two- to four-forked, rarely simple; 2 small, two- to four-forked; 3 represented only by its socket; 4 medium, two- or three-forked near base.

*Segment VI*: A small, simple spine; B very long, stout, simple; C medium, two- or three-forked near base, rarely simple; 1 medium, two-forked near base, rarely simple; 2 medium, usually three-forked near middle, occasionally two- to five-forked; 3 absent; 4 medium, two- or three-forked at basal one-third, rarely simple.

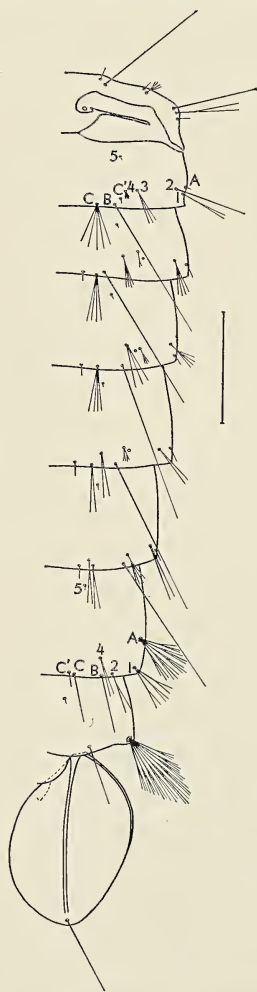


FIG. 36. *Aedes hollandius*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.

*Segment VII*: A moderate, four- to six-branched, each branch stout basally and apically three- or four-branched; B medium, simple; C medium, usually two-forked, occasionally simple or three-forked; 1 moderate, usually three-branched, range from two to five, each branch stout at base and apically two- or three-forked; 2 medium, usually two-forked near middle, rarely simple; 4 medium, usually two-forked near base, rarely simple or three-forked.

*Segment VIII*: A similar to A-VII but larger, six- to ten-branched, usually nine-branched, each branch stout basally but two- to three-branched or forked apically; A' medium, simple or two-forked.

*Paddle*: Roughly spoon-shaped, the apex somewhat pointed; margin smooth for the most part, but with very fine small teeth near apex; midrib strong, not reaching apex, dividing the paddle almost equally; terminal seta long, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of one male and five females from Hilimoi, Milne Bay, Papua.

*Aedes (Finlaya) novalbitarsis* King and Hoogstraal 1946

Fig. 37

**DIAGNOSIS.**—Very similar to *A. hollandius* but distinct from other *Finlaya* in having seta A-VIII dendritic.

**CEPHALOTHORAX.** — *Postocular*: 1 small, simple or two-forked, rarely three-forked; 2 medium, simple or two-forked; 3 long, simple. *Anterotothoracic*: 4 medium, three- or four-forked, rarely five-forked; 5 long, simple or rarely two-forked; 6 small, simple or rarely two-branched; 7 medium, two- or three-forked, occasionally simple or four-forked.

*Dorsal*: 8 long, about one-half the length of the trumpet, two- or three-forked, rarely simple.

*Supra-alar*: 9 small, simple or two-forked near apex.

*Metanotum*: 10 medium, simple or two- to three-forked; 11 long, more than half the length of the trumpet, simple; 12 medium, two-forked or occasionally three-forked.



*Trumpet*: Funnel-shaped, length about three times the greatest diameter of the meatus; pinna a little more than one-third of the total length of the trumpet; uniformly dark-pigmented.

**ABDOMEN.**—*Segment I*: H small, simple or rarely two-forked; K long, simple or rarely two-forked near apex; L small, two- or three-forked near base or occasionally five-forked; M small, three-forked, occasionally four- or five-forked; S long, simple or occasionally two-forked; T long, simple or two- or three-forked, rarely simple; U small, simple.

*Segment II*: A small, simple spine; B very long, simple; C medium, three- or four-branched or forked near base, occasionally two- or five-branched; C' small, simple on this and all following segments; 1 medium, two- to four-forked; 2 long, simple or two-forked; 3 small, two- or three-forked near base; 4 small, two- to four-forked near base, rarely simple or five-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B very long, sometimes slightly plumose apically, simple; C medium, two- to four-branched; 1 small, two- to four-forked, or rarely five-forked; 2 small, two- or three-forked, rarely four-forked; 3 represented only by its socket; 4 small, two- or three-forked.

*Segment IV*: A small, simple spine; B very long, sometimes slightly plumose apically, simple; C medium, two- to four-branched, rarely six-branched; 1 small, three- to five-forked, occasionally simple or two-forked; 2 small, two- or three-forked near apex or simple; 3 represented only by its socket; 4 medium, three- or four-forked.

*Segment V*: A small, simple spine; B very long, sometimes slightly plumose apically, simple; C small, two-forked or occasionally simple; 1 small, two- or three-forked near middle; 2 small, three- to five-forked near base or rarely two-forked; 3 represented only by its socket; 4 medium, two-forked near apex or occasionally three-forked.

*Segment VI*: A small, simple spine; B very long, sometimes slightly plumose apically, simple; C small, two-forked or occasionally three-forked

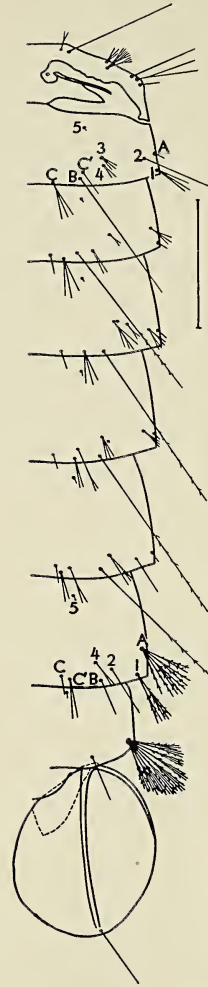


FIG. 37. *Aedes novalbitarsis*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.

or simple; 1 medium, simple or two-forked; 2 medium, three- or four-forked, rarely two-forked; 3 absent; 4 medium, two-forked or rarely simple.

*Segment VII*: A medium, stout, two- to six-branched, usually five, each branch being two- or three-branched at about the middle; B medium, simple or two-forked; C medium, two-branched, rarely simple; 1 medium, stout, similar to A, two- or three-branched; 2 medium, simple or rarely two-forked; 4 small, two-forked near middle or occasionally simple.

*Segment VIII*: A large, stout, conspicuous, five- to ten-branched, averages eight, each branch fur-

ther two- to four-branched; A' medium, simple or rarely two-forked near apex.

*Paddle*: Roundly oval, length not greatly exceeding width; margin very finely toothed apically, not obvious without high-power magnification; midrib strong, dividing the paddle almost equally, the medial face only slightly wider than the lateral face; terminal seta strong, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of twelve males and four females from Hilimoi, Milne Bay, Papua.

#### Subgenus MACLEAYA Theobald

A certain diagnosis of *Macleaya* is not possible at present since the single species assigned to this subgenus has not been completely described in the pupal stage.

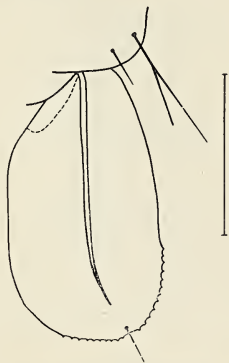


FIG. 38. *Aedes tremula*: right paddle (after Hill, 1925).

#### *Aedes (Macleaya) tremula* (Theobald) 1903 Fig. 38

Pupa undescribed, but Hill (1925: 72) included figures of the trumpet, posterior margin of segment VIII, and the paddles of specimens from Queensland, Australia. These have been redrawn and are included here.

If Hill's figures are correct, the elongate nature of the paddles (twice as long as wide) and the coarsely serrate apex should prove to be of diagnostic value for the species as well as the subgenus among the known *Aedes* of New Guinea.

#### Subgenus PSEUDOSKUSEA Theobald

The pupa of none of the three New Guinean species belonging here has been described.

#### Subgenus SKUSEA Theobald

**DIAGNOSIS**.—Only one species of *Skusea* has been recorded from New Guinea and only three or four from the whole Australasian Region, but these are distinct in the pupal stage from other *Aedes* in possessing wide paddles with a fringe of long fine hairs almost all around the margin, and in having the dorsal seta (8) of cephalothorax placed between the trumpets.

#### *Aedes (Skusea) dasyorrhus* King and Hoogstraal 1946

Fig. 39

**CEPHALOTHORAX**.—*Postocular*: 1 small, two- or three-forked; 2 very long, stout, two- or three-forked; 3 long, two-forked or simple.

*Anterotheracic*: 4 long, stout, three- or four-forked; 5 small, two- to four-forked, rarely simple; 6 small, simple; 7 medium, simple or occasionally two-forked.

*Dorsal*: 8 medium, about one-half length of trumpet, simple or two- to three-forked.

*Supra-alar*: 9 long, nearly equal to trumpet, two-forked or rarely simple.

*Metanotum*: 10 small, simple or two-forked, rarely three-forked; 11 long, simple; 12 medium, three- or four-forked, rarely simple or two-forked.

*Trumpet*: Small, length a little more than three times the greatest diameter of meatus; pinna a little more than one-fourth of total length; uniformly lightly pigmented.

**ABDOMEN**.—*Segment I*: H medium, simple; K long, simple; L small, two- or three-forked or simple; M medium, four- or five-forked, occasionally three-forked; S long, simple; T long, two- or three-forked; U small, simple.

*Segment II*: A small, simple spine; B long, simple; C long, four- or five-forked near basal fourth, or rarely three-forked; C' medium, simple; 1 medium, three- or four-forked near base; 2 long, two- or three-forked or occasionally simple; 3 small, two- to four-forked near middle; 4 small, two- to four-forked near middle.

*Segment III*: A small, simple spine; B long, simple or rarely two-forked at apex; C small, simple or two-forked; C' small, simple on this



and all following segments; 1 medium, simple; 2 small, two-forked near apex or simple, rarely three-forked; 3 represented only by its socket; 4 small, two- or three-forked, rarely simple.

*Segment IV*: A small, simple spine; B very long, exceeding posterior margin of segment V, simple; C medium, two- or three-forked, rarely simple; 1 medium, two-forked or simple; 2 small, two-forked or occasionally simple; 3 represented only by its socket; 4 small, three- to five-forked.

*Segment V*: A small, simple spine; B very long, simple; C medium, usually two-forked near base, occasionally three-forked; 1 medium, simple or two-forked; 2 medium, four- or five-forked; 3 represented only by its socket; 4 medium, two-

forked or simple, rarely three-forked near apex. *Segment VI*: A small, simple spine; B very long, simple; C small, simple or two- to three-forked near middle; 1 long, simple or two-forked near base; 2 small, two-forked near middle or occasionally three-forked; 3 absent; 4 medium, two-forked or rarely simple.

*Segment VII*: A medium, two-forked or rarely simple; B long, simple or occasionally two-forked near apex; C long, two-forked or occasionally simple; 1 small, usually two-forked, range from simple to four-forked; 2 small, two-forked or simple; 4 medium, simple.

*Segment VIII*: A long, stout, six- to ten-branched, most often eight-branched; A' medium, simple or two-forked near middle.

*Paddle*: Laterally rounded more or less evenly, medially the apical half produced into a wide lobe; margin with a fringe of long hairs interrupted only at the tip of the midrib; midrib strong, dividing paddle unequally, the lateral face being about three-fourths the width of the medial face; terminal seta strong, long, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of seven males and four females from Hilimoi, Milne Bay, Papua.

#### Subgenus GEOSKUSEA Edwards

None of the four species assigned to *Geoskusea* has been described in the pupal stage. Only one species has been recorded from New Guinea.

#### Subgenus STEGOMYIA Theobald

**DIAGNOSIS.**—Although many of the species of this subgenus have been described in the pupal stage, *Stegomyia* is rather hard to separate definitely from all other subgenera in the New Guinea area. Edwards (1941: 387) used the position of the dorsal seta (8) of the cephalothorax as diagnostic, but this is a relative character which is encroached upon by certain species of other subgenera. For the most part, however, species of *Stegomyia* may be distinguished by having the dorsal seta placed well behind the bases of the trumpets, i.e., at least halfway between the trumpets and the anterior margin of the metanotum, instead of between them or



FIG. 39. *Aedes dasyorrbus*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.





*Segment III:* A small, simple spine; B long, simple; C long, two-branched, very rarely five-branched; 1 long, simple, very rarely two-forked; 2 small, two-forked near middle or rarely three-forked or simple; 3 represented only by its socket; 4 small, two-forked or simple, occasionally three- or four-forked.

*Segment IV:* A small, simple spine; B long, simple or very rarely two-forked; C long, two-forked near base, rarely simple or three-forked; 1 medium, simple; 2 medium, two-forked or simple; 3 represented only by its socket; 4 medium, two- or three-forked, rarely simple or three-forked.

*Segment V:* A small, simple spine; B long, simple; C medium, two-forked or occasionally simple; 1 medium, simple; 2 medium, two-forked, occasionally three-forked, rarely simple; 3 represented only by its socket; 4 medium, simple or rarely two-forked.

*Segment VI:* A slightly longer than A-V, simple; B long, simple; C medium, simple or occasionally two-branched; 1 medium, simple; 2 medium, two-forked near middle or simple; 3 absent; 4 medium, simple.

*Segment VII:* A medium, simple; B long, simple; C medium, simple; 1 small, simple or occasionally two-forked; 2 medium, simple; 4 medium, simple or rarely two-forked.

*Segment VIII:* A long, two-branched with small side branches at middle, occasionally simple or three- to four-branched; A' medium, simple or two-forked near apex.

*Paddle:* Oval with apex more or less pointed; margin with a fringe of long fine hairs; midrib strong, dividing the paddle almost equally; terminal seta long, strong, simple or occasionally two-forked.

**SPECIMENS EXAMINED.**—The pupal exuviae of 34 males and 33 females from Hilimoi and KanaKope, Milne Bay, Papua; Draeger Harbor, Northeast New Guinea; and Mios Woendi, Dutch New Guinea.

*Aedes (Stegomyia) albopictus* (Skuse) 1895

The pupa of *A. albopictus* has received considerable attention. Banks (1908: 246) gave

brief notes on it, without figures, as *Stegomyia samarensis*; Baisas (1938: 181) gave a figure of the abdomen and paddles without description; Edwards (1941: 391) reproduced Baisas' figure and gave a diagnostic description; and Taylor (1943: 159; 1944: 87) reproduced Baisas' figure without description.

**DIAGNOSIS.**—Very similar to *A. scutellaris* and impossible to separate on the basis of published descriptions alone. Edwards lists the following features: seta A-II-V quite small and pale, A-VI twice as long and dark, A-VII still longer and quite simple; A-VIII single or forked or with a few short branches at some distance from base. Paddle more or less pointed and with a fringe of long hairs.

*Aedes (Stegomyia) aegypti* (Linnaeus) 1762  
Fig. 41

The pupa of this species has received a great deal more attention than that of any other mosquito. The most detailed study of its chaetotaxy was that of Macfie (1920: 161) based on ten specimens from West Africa. *Aedes aegypti* pupae have been variously included in numerous other papers and the figures and descriptions presented have varied from the very briefest mention to rather complete diagnoses, but none has approached the completeness of Macfie's descriptions. Other than Macfie, authors who have published on this species include Mitchell (1907: 253), Banks (1908: 243), Wesche (1910: 25), Howard, Dyar, and Knab (1912-1917 [vol. 2]: pl. 150; [vol. 4]: 824), Theodor (1924: 344), Cooling (1924: 13), Buxton and Hopkins (1925: 300), Kirkpatrick (1925: 87), Buxton and Hopkins (1927: 113), Edwards (1941: 388), Taylor (1943: 152), Parr (1943: 250), Taylor (1944: 80), and Bohart and Ingram (1946: 6).

Although *A. aegypti* is recorded from New Guinea, we did not succeed in collecting specimens. Accordingly, the description which follows and the figure have been taken, with modifications, from Macfie.

**DIAGNOSIS.**—Readily separated from other

*Stegomyia* in having the apical paddle margin serrate and terminal seta short and simple.

**CEPHALOTHORAX.**—*Postocular*: 1 moderate, usually simple, occasionally two-branched; 2 small, usually two-branched, occasionally simple; 3 moderate, simple.

*Anterothoracic*: 4 moderate, two- or three-forked; 5 moderate, simple or two- to three-branched; 6 long, stout, simple; 7 moderate, usually two-branched, occasionally simple.

*Dorsal*: 8 small, usually two-branched, occasionally simple or three-branched.

*Supra-alar*: 9 long, simple.

*Metanotum*: 10 moderate, usually two-branched, occasionally simple or three-branched; 11 long, stout, simple; 12 moderate, simple or two-branched.

**ABDOMEN.**—*Segment I*: H long, stout, simple; K long, stout, simple or two-branched; L small, two- to four-branched; M small, two- to five-branched; s long, simple or two-branched; T long, simple or two-branched; U small, simple.

*Segment II*: A short, stout; B long, simple or two-branched; C moderate, usually two- to three-branched, occasionally simple; C' moderate, simple; 1 long, simple or two-branched; 2 long, simple or two-branched; 3 moderate, simple or two- to three-branched; 4 small, two- to five-branched; 5 minute, simple.

*Segment III*: A short, stout, slightly longer than A-II, simple; B long, simple or two-forked; C moderate, usually simple or two-branched, occasionally up to five-branched; C' small, relatively stout, simple; 1 long, simple or occasionally two-branched; 2 moderate, simple or two-branched, occasionally three-branched; 3 represented only by its socket; 4 small, two- to four-forked or simple.

*Segment IV*: A short, stout, a little longer than A-III; B long, simple; C moderate, simple or two-forked; C' small, rather stout, simple; 1 long, usually simple, occasionally two- or three-branched; 2 small, simple or two- to three-forked; 3 represented only by its socket; 4 moderate, two- or three-forked.

*Segment V*: A stout, a little longer than A-IV;

B long, simple, occasionally two-branched; C moderate, simple or two-branched; C' short, relatively stout, simple; 1 long, simple, occasionally two-branched; 2 small, usually two-forked, occasionally simple or three-forked; 3 represented only by its socket; 4 moderate, simple or two-forked.

*Segment VI*: A stout, a little longer than A-V, simple or forked near apex; B long, simple; C small, simple or two-branched; C' small, stout, simple; 1 long, simple or occasionally two-branched; 2 moderate, usually two-branched, occasionally simple; 3 absent; 4 moderate, simple or occasionally two-branched.

*Segment VII*: A long, sometimes plumose, sim-

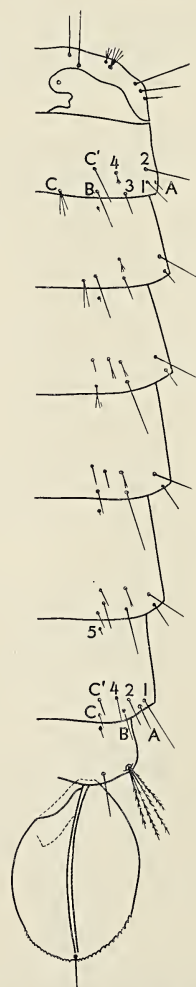


FIG. 41. *Aedes aegypti*: dorsal aspect of right half of abdomen of male (after Macfie, 1920).



ple or two-branched; B long, simple; C small, simple; C' small, rather stout, simple; 1 moderate, simple or occasionally two- to three-branched; 2 long, simple; 4 small, simple or two-branched.

*Segment VIII*: A strong, long, plumose, usually four-branched, range from two to five; A' long, simple.

*Paddle*: Roughly oval, margin smooth on basal two-thirds, then serrate around apex to same point on medial side; midrib strong, dividing the paddle almost equally; terminal seta long, simple.

*Aedes (Stegomyia) albolineatus* (Theobald) 1904

Fig. 42

**DIAGNOSIS**.—Distinct in having the terminal seta of the paddle long and with three or more stout plumose branches.

**CEPHALOTHORAX**.—*Postocular*: 1 long, two-forked or simple, rarely three-forked; 2 medium, simple or rarely two-forked; 3 long, simple or occasionally two-forked.

*Anterotheracic*: 4 long, stout, simple or occasionally two-forked; 5 medium, two- or three-forked, rarely simple or four-forked; 6 small, usually simple, occasionally two- or three-forked at apex; 7 medium, simple or two-forked.

*Dorsal*: 8 medium, one-half length of trumpet, two-forked or occasionally simple or three-forked.

*Supra-alar*: 9 medium, simple.

*Metanotum*: 10 medium, usually two-forked, occasionally simple or three-forked; 11 long, simple; 12 long, three- or four-forked, occasionally simple.

*Trumpet*: Funnel-shaped, length about three times greatest diameter of meatus; pinna one-third to one-fourth of total length; very lightly pigmented.

**ABDOMEN**.—*Segment I*: H medium, stout, simple or rarely two-forked at apex; K very long, stout, simple; L medium, three- to six-forked above base; M medium, five- to seven-forked above base; S very long, simple; T long, usually two-forked near middle, occasionally simple or

three-forked; U small, simple.

*Segment II*: A small, simple spine; B long, simple; C medium, two-forked near base or occasionally simple; C' small, simple; 1 medium, simple or two- to three-forked; 2 long, simple; 3 medium, usually two-forked, occasionally simple or three-forked; 4 small, usually three-forked above base, occasionally two- or four-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple or rarely two-forked at apex; C medium, two-forked or rarely simple; C' small, simple or rarely two-forked at apex; 1 long, simple; 2 small, two-forked or occasionally simple or three-forked; 3 represented only by its socket; 4 medium, two-forked or occasionally simple or three-forked.

*Segment IV*: A small, simple spine; B very long, almost reaching to posterior margin of segment VI, simple; C long, two-forked near base; C' small, simple; 1 long, simple; 2 medium, two-forked near basal third; 3 represented only by its socket; 4 medium, four- or five-forked, rarely two-forked.

*Segment V*: A small, simple spine; B very long, simple; C long, two-forked near base or occasionally simple; C' small, simple or occasionally two-forked apically; 1 long, simple; 2 small, usually five-forked near basal third, occasionally three- or two-forked; 3 represented only by its socket; 4 long, simple or two-forked.

*Segment VI*: A small, simple spine; B long, simple or occasionally two-forked near apex; C medium, simple or rarely two-forked near apex; C' small, simple; 1 long, simple; 2 medium, two- or three-forked, rarely simple or four-forked; 3 absent; 4 medium, simple or two-forked at apex.

*Segment VII*: A long, plumose, three-branched or occasionally two- or four-branched; B long, simple; C medium, simple; C' small, simple or rarely two-forked apically; 1 long, plumose, usually two-branched, occasionally three-branched or simple; 2 medium, two-forked near basal one-fourth, or occasionally simple; 4 medium, simple or occasionally two-forked.

*Segment VIII*: A very long, plumose, seven- to fourteen-branched, averages eleven-branched; A' medium, simple or two-forked near middle.

*Paddle*: Oval, length always exceeding width by one-fourth; margin very slightly and finely serrate laterally, smooth medially; midrib strong, dividing paddle almost equally, but medial face slightly wider than lateral face; terminal seta strong, plumose, usually three-branched, occasionally as many as six-branched.

**SPECIMENS EXAMINED.**—The pupal exuviae of eleven males and ten females from Waga-Waga, Hilimoi, and KanaKope, Milne Bay, Papua, and Mios Woendi, Dutch New Guinea.

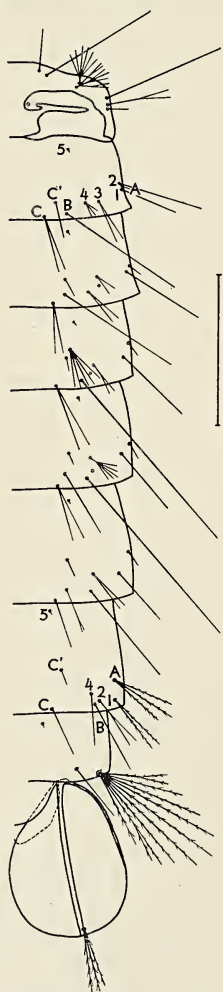


FIG. 42. *Aedes albolineatus*: dorsal aspect of right half of abdomen of male from Mios Woendi, Dutch New Guinea.

### Subgenus AEDIMORPHUS Theobald

**DIAGNOSIS.**—Dorsal seta (8) of cephalothorax placed between or slightly behind the bases of the trumpets. Seta B comparatively short on all abdominal segments, never reaching posterior margin of the following segment; setae B and C either branched or forked on most of the segments.

*Aedes (Aedimorphus) vexans* (Meigen)  
1830

Fig. 43

Pupa never fully described heretofore although brief notes and illustrations of parts of it have been included in papers by several authors including Mitchell (1907: 257), Howard, Dyar, and Knab (1912–1917 [vol. 2]: fig. 702; [vol. 4]: 694), Buxton and Hopkins (1927: 91), Matheson (1944: 27), and Bohart and Ingram (1946: 15).

**CEPHALOTHORAX.** — *Postocular*: 1 small, simple; 2 medium, simple or two-forked; 3 medium, two-forked.

*Anterotheracic*: 4 medium, two-forked near apex; 5 medium, two- or three-forked; 6 small, simple or two-forked; 7 medium, two- or three-branched.

*Dorsal*: 8 medium, two- or three-forked.

*Supra-alar*: 9 medium, two-forked.

*Metanotum*: 10 medium, four- to six-branched; 11 medium, simple; 12 medium, simple to three-forked.

*Trumpet*: Funnel-shaped, short, length about two and one-half times greatest diameter of meatus; pinna equal to about one-fourth of total length; uniformly dark pigmented.

**ABDOMEN.**—*Segment I*: H small, simple; K medium, simple; L very small, two- to five-branched; M very small, simple or three-forked; S long, simple; T medium, two- or three-forked near middle; U very small, simple.

*Segment II*: A small, simple spine; B medium, simple; C medium, four- to seven-branched; C' small, simple spine on this and all following segments; 1 medium, two- or three-forked near basal one-third; 2 long, simple; 3 medium,



*Segment IV:* A small, simple spine; B long, two- or three-branched; C medium, three- or four-forked near base; 1 long, simple; 2 small, two-forked near middle; 3 represented only by its

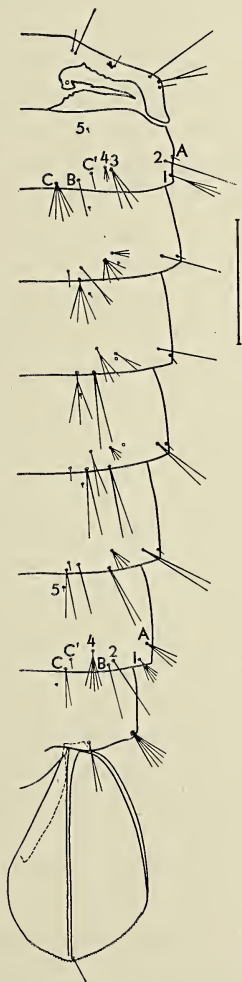


FIG. 43. *Aedes vexans*: dorsal aspect of right half of abdomen of male from Gamadodo, Papua.

SPECIMENS EXAMINED.—The pupal exuviae of two males from Gamadodo, Milne Bay, Papua.

## Subgenus BANKSINELLA Theobald

DIAGNOSIS.—According to Edwards (1941: 399), the species of *Banksinella* are distinct from all other *Aedes* in having setae H and K wide apart and K forming a small tuft, little if any larger than L or M, instead of a long simple seta. On the metanotum, the simple seta 10 is in front of seta 11 instead of medial to it. None of the abdominal setae strongly developed, but C-II forming a small tuft which may be dendritic. A-VII and A-VIII very small. Paddles with weak midrib and smooth margin.

The pupa of the single species recorded from New Guinea is unknown.

### Subgenus *Aedes* Meigen

Heretofore only one species of the subgenus *Aedes* has been partially described, and since we collected pupae of only one additional species in New Guinea the following notes must be taken with reservations as a subgeneric diagnosis.

**DIAGNOSIS.**—Setae H and K close together, well separated from L and M. At least B-IV and V long, reaching posterior margins of following segments, usually two- or more branched; seta C-II a medium-length multibranched tuft which is often dendritic.

#### *Aedes (Aedes) funereus* (Theobald) 1903

Pupa undescribed, but Hill (1925: 73) included figures of the paddles and trumpet. Since no differences between these figures and specimens of *A. lineatus* were noted, the figures are not included here.

#### *Aedes (Aedes) lineatus* (Taylor) 1914

Fig. 44

**CEPHALOTHORAX.**—*Postocular*: 1 medium, two-forked, rarely three-forked; 2 medium, simple or rarely two-forked; 3 medium, two-forked near middle or rarely three-forked.

*Anterothoracic*: 4 medium, two- or three-forked; 5 medium, two- to six-forked; 6 small, simple; 7 medium, two- to four-forked.

*Dorsal*: 8 medium, less than one-half the length of the trumpet, three- to five-forked, rarely six- or eight-forked.

*Supra-alar*: 9 medium, two- or three-forked, rarely simple.

*Metanotum*: 10 medium, usually four-forked, range from three- to seven-forked; 11 long, longest seta on cephalothorax, simple; 12 medium, two- to six-forked.

*Trumpet*: Short, funnel-shaped, length ranging from about two to three times greatest diameter of meatus; pinna short; all darkly pigmented, but tracheoid area darkest.

**ABDOMEN.**—*Segment I*: H medium, stout, simple spine; K medium, two- or three-forked near base; L small, usually two-forked, occasionally three- or four-forked; M small, two- to five-forked; S long, simple or occasionally two-forked; T medium, two- to four-forked near middle, rarely five-forked; U small, simple.

*Segment II*: A small, simple spine; B long, simple; C medium, ten- to fifteen-branched tuft; C' small, simple on this and all following segments; 1 medium, two- or three-forked near middle; 2 long, simple or rarely two-forked; 3 medium, two- to four-branched, each branch being two-forked near its middle; 4 small, two- or four-forked near base; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple; C medium, three- to eight-branched; 1 medium, two- or three-forked, occasionally four- or five-forked; 2 small, simple; 3 represented only by its socket; 4 medium, three- or four-forked.

*Segment IV*: A small, simple spine; B long, two-branched or rarely three-branched; C medium, three- to six-branched; 1 medium, three- or four-forked near middle, rarely simple; 2 small, two-forked near apex or simple; 3 represented only by its socket; 4 medium, two- to six-forked near middle.

*Segment V*: A small, simple spine; B long, two-branched or occasionally two-forked; C medium, three- or four-branched; 1 medium, two- or three-forked near middle, rarely simple; 2 medium, two- to five-forked near base; 3 represented only by its socket; 4 medium, two- or three-forked near apex.

*Segment VI*: A small, simple spine; B long, simple or two-branched; C medium, three- or four-branched; 1 medium, simple; 2 medium, two- to five-forked near basal one-third; 3 absent; 4 medium, two-forked near basal one-third or simple, rarely three-forked.

*Segment VII*: A medium, two-branched or rarely simple; B medium, two-branched or rarely simple; C medium, two- to four-branched; 1 small, two- to four-forked near base; 2 medium, two-



or three-forked near basal third; 4 medium, two- or three-forked near basal one-third.

*Segment VIII:* A medium, stout, four- to eight-branched, plumose; A' medium, simple to three-forked near apex.

*Paddle*: Roughly oval, longer than wide, margin very finely serrate laterally and apically; midrib strong, not reaching apex, dividing the paddle almost equally; terminal seta medium, simple.

SPECIMENS EXAMINED.—The pupal exuviae of one male and three females from Gamadodo and Waga Waga, Milne Bay, Papua, and Draeger Harbor, Northeast New Guinea.

## Subgenus LEPTOSOMATOMYIA Theobald

DIAGNOSIS.—The following is based on the single species of the subgenus which is known in its immature stages. All dorsal abdominal setae on segments II–VIII small, inconspicuous, and usually simple, except A–VII and A–VIII. The latter two are large, several-branched plumose tufts. Paddles reminiscent of those of *Tripteroides* in general shape, though larger of course, produced apically into a truncate point.

*Aedes (Leptosomatomyia) aurimargo*  
Edwards 1922

Fig. 45

CEPHALOTHORAX. — *Postocular*: 1 small, three- or four-forked, rarely six-forked; 2 small, simple or two-forked; 3 small, two-forked.

*Anterothoracic*: 4 medium, two-forked near middle or occasionally simple; 5 medium, two-forked near middle or rarely simple; 6 small, simple; 7 medium, two-forked near middle or simple.

*Dorsal:* 8 small, about one-half the length of the trumpet, simple or occasionally two-forked near base.

*Supra-alar:* 9 small, simple.

*Metanotum*. 10 and 11 very close together, well separated from 12; 10 small, simple or two- to three-forked; 11 medium, simple; 12 small, two-forked near middle or occasionally three-forked.

*Trumpet:* Small, funnel-shaped, length usually not more than twice the greatest width; pinna short, ranging from one-fourth to one-sixth of the total length of the trumpet; uniformly dark-pigmented.

ABDOMEN.—*Segment 1*: H medium, simple; K long, simple; 1 small, two-forked near middle; M small, four- or five-forked near middle; S long, simple; T long, two-forked near base; U minute, simple.

*Segment II:* A small, simple spine; B medium, stout, simple; C long, stout, simple; C' medium, usually simple or two- to three-forked; 1 small, simple or two- to three-forked, rarely four-forked; 2 medium, simple or rarely two-forked; 3 small, two- to five-forked; 4 medium, stout,

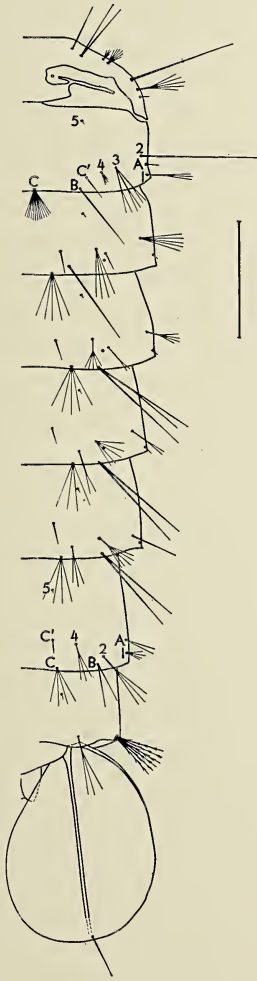


FIG. 44. *Aedes lineatus*: dorsal aspect of right half of abdomen of female from WagaWaga, Papua.

simple; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B medium, stout, simple; C long, stout, simple; C' small, simple spine on this and all following segments; 1 small, simple; 2 small, simple or rarely two-forked; 3 represented only by its socket; 4 small, simple spine.

*Segment IV*: A small, simple spine; B long, stout, simple; C small, two-forked or occasionally simple; 1 small, simple or rarely two-forked; 2 small, simple or occasionally two-forked; 3 represented only by its socket; 4 small, four- or five-forked, rarely six-forked.



FIG. 45. *Aedes aurimargo*: dorsal aspect of right half of abdomen of male from Draeger Harbor, Northeast New Guinea.

*Segment V*: A small, simple spine; B long, stout, simple; C medium, simple; 1 small, simple; 2 small, five- or six-forked, occasionally two- to four-forked; 3 represented only by its socket; 4 small, two-forked or simple.

*Segment VI*: A small, simple; B medium, stout, simple; C small, simple, stout; C' small, stout spine, simple or rarely two-forked at apex; 1 small, simple; 2 small, two- to four-forked near middle; 3 absent; 4 small, simple, stout, rarely two-forked at apex.

*Segment VII*: A long, stout, black, plumose, two- to four-branched; B small, simple or occasionally two-forked near middle; C small, simple; 1 small, three-forked, rarely two-forked; 2 small, simple or two-forked; 4 small, simple.

*Segment VIII*: A very large, black, stout, plumose, five- to nine-branched, usually nine; A' long, simple.

*Paddle*: Long, narrow oval, apically with a blunt point; margin slightly serrate laterally becoming coarser near apex; midrib strong basally, declining apically, dividing paddle unequally, the lateral face being nearly twice the width of the medial face; terminal seta stout, black, usually two-branched or forked, rarely simple or three-forked.

**SPECIMENS EXAMINED.**—The pupal exuviae of four males and two females from Draeger Harbor, Northeast New Guinea.

#### Genus *ARMIGERES* Theobald

**DIAGNOSIS.**—Trumpets of moderate length, tracheoid portion obsolete, pinna very oblique. Dorsal seta (8) of cephalothorax placed far posterior to trumpets. Setae H and K close together, well separated from L and M. Seta A a small simple spine on segments II–VI, but a strong plumose tuft on VII and VIII; seta B a long simple seta on segments II–V, same length throughout but closer to lateral margin on the posterior segments; seta C a small tuft on segments II–VII. Paddles fringed with long hairs around apical one-half of margin, with an irregular line of black pigment at base; midrib strongest on basal one-third; terminal seta strong, accessory seta absent.



Key to Species of *Armigeres*

- Setae B and C on segment II placed close together; C-II a small three- or four-branched tuft; paddle not notched at apex (Fig. 46).....*A. breinli*
- Setae B and C on segment II placed relatively far apart; C-II a conspicuous five- or six-forked tuft; paddle notched at apex (Fig. 47).....*A. milnensis*

*Armigeres breinli* (Taylor) 1914

Fig. 46

CEPHALOTHORAX.—*Postocular*: 1 small, five- or six-branched; 2 long, two- or three-branched; 3 long, two-branched.

*Anterothoracic*: 4 small, three- to five-forked; 5 small, five- or six-forked; 7 small, two-forked or rarely simple; 6 long, stout, pale, simple.

*Dorsal*: 8 medium, five-forked.

*Supra-alar*: 9 small, three-forked.

*Metanotum*: 10 medium, four-branched; 11 long, stout, simple; 12 small, six-branched.

*Trumpet*: Short, length about twice the greatest diameter of meatus; pinna long, about one-half the total length of trumpet; tracheoid area obsolete; uniformly light-pigmented.

ABDOMEN.—*Segment I*: H medium, stout, simple; K long, stout, plumose, simple; L very small, simple; M small, six-branched; S medium, three-branched; T medium, five- or six-branched; U very small, simple.

*Segment II*: A small, simple spine; B long, simple, plumose; C small, three- or four-branched; 1 small, four- or five-branched; 2 very small, three-branched; 3 very small, four- to six-branched; 4 medium, simple; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple, plumose; C very small, three- or four-branched; C' small, simple on this and all following segments; 1 very small, two- or three-branched; 2 very small, three-branched; 3 represented only by its socket; 4 small, three-branched.

*Segment IV*: A small, simple spine; B long, simple, plumose; C small, five-branched; 1 very small, simple or two-forked; 2 small, three- to

five-forked; 3 represented only by its socket; 4 small, three-forked.

*Segment V*: A small, simple spine; B long, simple, plumose; C small, five-branched; 1 small, simple to four-branched; 2 small, two- to four-forked; 3 represented only by its socket; 4 small, three- or four-forked.

*Segment VI*: A small, simple spine; B long, two-branched, plumose; C small, three-branched; 1 small, two- or three-forked, mesad of B in position; 2 small, two- to five-forked; 3 absent; 4 small, four- to seven-forked, mesad of C in position.



FIG. 46. *Armigeres breinli*: dorsal aspect of right half of abdomen of female from Mios Woendi, Dutch New Guinea.

*Segment VII:* A large, strong, plumose, five- to eight-branched; B size various, from small to long on different specimens, usually three-branched, placed very close to A; C small, four-branched; 1 small, four-branched; 2 very small, two-branched; 4 very small, three-branched.

*Segment VIII:* A large, strong, plumose, subequal to A-VII, seven- or eight-branched; A' very small, four- or five-forked.

*Paddle:* Elongate, more or less blunt-tipped, medially produced into a wide flap, medial face one-third wider than lateral face; midrib strong basally, disappears at about middle; margin with a fringe of long hairs almost all around; with an irregular line of black pigment at base of paddle; terminal seta strong, two- or three-forked.

**SPECIMENS EXAMINED.**—The pupal exuviae of fourteen males and seven females from Hili-moi, Milne Bay, Papua; Draeger Harbor, North-east New Guinea; Mios Woendi and Amsterdam Island, Dutch New Guinea.

### *Armigeres milnensis* Lee 1944

Fig. 47

**CEPHALOTHORAX.**—*Postocular:* 1 long, stout, black, plumose, nearly equal to length of trumpet, two-branched; 2 absent; 3 long, stout, black, plumose apically, simple.

*Anterothoracic:* 4 small, four- or five-branched; 5 small, four-branched; 6 long, stout, pale, simple; 7 medium, black, two-forked.

*Dorsal:* 8 medium, four-forked.

*Supra-alar:* 9 medium, two-forked.

*Metanotum:* 10 medium, seven- or eight-forked; 11 long, stout, black, simple; 12 small, four-branched.

*Trumpet:* Short, length about twice greatest diameter of meatus; tracheoid portion obsolete; pinna long, nearly one-half the total length of trumpet; pale-brown colored, darker than cephalothorax.

**ABDOMEN.**—*Segment I:* H small, simple; K long, simple, plumose, rarely two-forked near apex; L very small, simple or two-forked; M

very small, usually six- to eight-forked near middle, range from four to thirteen; S small, usually three-branched, range from two- to six-branched; T small, usually three-branched, range from two- to six-branched; U very small, two-forked near base or simple.

*Segment II:* A small, simple spine; B long, plumose, simple; C medium, usually five- or six-forked from near base, range from four to nine; 1 small, usually six-branched, range from four to seven; 2 small, usually three-forked, range from two to six; 3 very small, usually four- to six-branched, range from four to ten; 4 small, simple; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B very long, plumose, simple; C small, usually three- or four-branched, rarely five- to seven-branched; C' small, simple on this and all following segments; 1 small, either two-, three-, or four-branched; 2 very small, two- to five-forked from near base; 3 represented only by its socket; 4 small, three- or four-branched or forked.

*Segment IV:* A small, simple spine; B very long, plumose, simple; C small, variable, usually four-branched, but ranges from two to eight; 1 small, usually three- to four-branched, rarely two- or five-branched; 2 small, usually three- or four-branched, rarely two- or five-branched; 3 represented only by its socket; 4 small, usually four-branched, range from two to five.

*Segment V:* A small, simple spine; B very long, plumose, simple; C small, usually three- or four-branched, rarely five- to seven-branched; 1 small, usually three-branched, range from two to five; 2 very small, usually four- or five-branched, rarely two- or three-branched; 3 represented only by its socket; 4 small, three- or four-branched.

*Segment VI:* A small, simple spine; B long, stout, black, plumose, simple or two-branched, only rarely three-branched; C very small, two- or three-forked near base, occasionally four-forked; 1 very small, two- or three-forked; 2 small, usually three-forked near base, occasionally two- or four-forked; 3 absent; 4 small, two- or three-forked, rarely simple or four-forked.



*Segment VII:* A long, stout, black, plumose, very similar to B-VI, three- or four-branched, rarely two-branched or forked; B small, various, two- to six-forked near base; C very small, simple or two-forked near base; 1 small, two- or three-forked near base, rarely simple; 2 very small, two-forked near base or simple; 4 small, usually three-forked near base, occasionally simple or two- to four-forked.

*Segment VIII:* A very long, large, conspicuous, black, plumose tuft, range from six- to eleven-branched, usually nine-branched; A' small, two- or three-branched, occasionally simple or four-branched.

*Paddle*: Roundly oval, slightly longer than wide; with a fringe of long fine hairs on the margin starting at the apical one-third laterally and extending to the apical one-half medially; midrib stronger than in *breinli*, dividing the paddle almost equally into halves; with an irregular broken line of black pigment across basal part of paddle; terminal seta medium, strong, simple.

SPECIMENS EXAMINED.—The pupal exuviae of two males and eight females from Hilimoi, Milne Bay, Papua, and Draeger Harbor, Northeast New Guinea.

*Armigeres lacuum* Edwards 1922

Pupa undescribed, but Hill (1925: 70) included figures of the trumpets, terminal abdominal segments, and paddles. These figures are not included here since they lack the detail necessary to bring out features which would distinguish *A. lacuum* from the other species in New Guinea.

Genus *CULEX* Linnaeus

DIAGNOSIS.—The pupae of *Culex* can usually be distinguished from those of other genera by the presence of an accessory seta situated beside the terminal seta at the tip of the midrib of the paddle, and by the presence of a small spine-like seta on the postero-lateral corner of segment IX. These features are both somewhat difficult to appreciate on all specimens and are not absolutely diagnostic because the New Guinean species of the subgenus *Acallyntrum* have neither terminal nor accessory paddle setae, and the accessory seta is absent from *C. squamosus*; seta v-IX is extremely difficult to see on most species and apparently is not always present on *C. sitiens*. Two other features characterize the large majority of *Culex* pupae, though again there are exceptions; the trumpets have a dark tracheoid area close to the base; and setae A-VII and A-VIII, which usually form well-marked plumose tufts, are placed well before the corners of the segments. The dorsal seta (8) of cephalothorax is usually placed well behind the bases of the trumpets.



FIG. 47. *Armigeres milnensis*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

## Subgenus LUTZIA Theobald

**DIAGNOSIS.**—Practically inseparable as a subgenus from *Culex* (*Culex*) except in the position of seta A on III–VI far anterior to the corners of the segments; the paddles slightly notched at the apex of the midrib; and always of large size.

*Culex* (*Lutzia*) *halifaxii* Theobald 1903

## Fig. 48

Pupa undescribed, but Hill (1925: 73) included figures of its paddles and trumpet.

**CEPHALOTHORAX.**—*Postocular*: 1 small, simple; 2 small, simple or occasionally two-forked at apex; 3 small, simple.

*Anterothoracic*: 4 small, simple; 5 small, simple; 6 small, simple; 7 small, simple.

*Dorsal*: 8 small, one-third length of trumpet, simple or rarely two-forked.

*Supra-alar*: 9 small, simple.

*Metanotum*: 10 small, three- or four-forked, or rarely five-forked; 11 small, simple or rarely two-forked; 12 small, simple.

*Trumpet*: Medium length, length about three times the greatest diameter of meatus; pinna long, nearly one-half the total length of trumpet; tracheoid area indistinct; basal part of trumpet darkest, although the whole trumpet is darkly pigmented.

**ABDOMEN.**—*Segment I*: H small, simple; K long, two-forked near basal one-third; L small, two-forked near apex, or occasionally five-forked or simple; M small, two- to four-forked near apex; s long, simple; t long, simple or rarely two-forked; U minute, simple.

*Segment II*: A small, simple spine; B long, simple or rarely two-forked near middle; C small, three- to five-forked near middle; C' small, simple on this and all following segments; 1 long, simple or rarely two-forked; 2 long, simple; 3 small, two- to four-forked or rarely simple; 4 long, simple; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple or occasionally two-forked; C long, plumose, five- to eight-forked near base; 1 me-

dium, simple; 2 small, two- or three-forked at apex; 3 represented only by its socket; 4 long, two- to four-forked, rarely simple or five-forked.

*Segment IV*: A small, simple spine; B long, plumose, three- to six-branched; C long, plumose, three- to six-branched; 1 long, simple or rarely two-forked at apex; 2 small, two-forked near apex, or rarely three-forked; 3 represented only by its socket; 4 small, five-forked near middle, or occasionally four- or six-forked.

*Segment V*: A small, simple spine; B very long, plumose, two- or three-branched, rarely four-branched; C very long, plumose, two- or three-branched; 1 long, simple; 2 medium, three- or

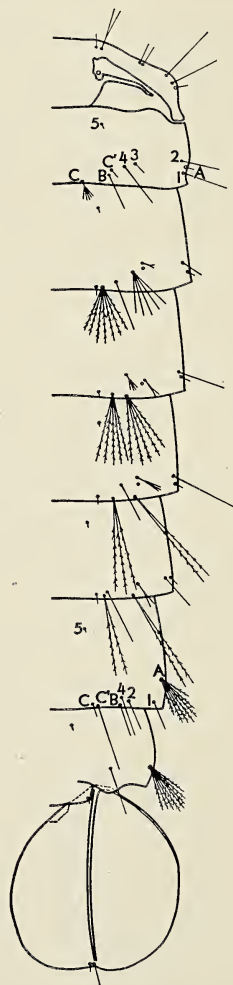


FIG. 48. *Culex halifaxii*: dorsal aspect of right half of abdomen of female from WagaWaga, Papua.



four-forked near middle; 3 represented only by its socket; 4 medium, simple or rarely two-forked.

*Segment VI*: A small, simple spine; B very long, plumose, two- or three-branched; C long, plumose, two- or three-branched; 1 medium, simple or occasionally two-forked; 2 medium, two-forked near middle or occasionally four-forked; 3 absent; 4 long, simple or rarely two-forked.

*Segment VII*: A long, plumose, four- to eight-branched, most frequently seven-branched; B medium, simple; C long, simple; 1 small, two-forked or rarely simple; 2 medium, simple; 4 medium, simple.

*Segment VIII*: A long, plumose, nine- to thirteen-branched, most frequently eleven-branched; A' long, simple.

*Segment IX*: v minute, stout, simple.

*Paddle*: Rounded, slightly longer than greatest width, apex with a notch at end of midrib; margin smooth; midrib dividing paddle unequally, lateral face a little wider than medial face; terminal seta very small, simple; accessory seta a little longer, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of three males and seven females from Gama-dodo, WagaWaga, and Hilimoi, Milne Bay, Papua.

#### Subgenus *NEOCULEX* Dyar

None of the four species recorded from New Guinea has been seen in the pupal stage, and so few pupae of *Neoculex* have been described that it is impossible to present a subgeneric diagnosis at the present time.

#### Subgenus *MOCHTHOGENES* Edwards

**DIAGNOSIS.**—Only two of the species of this subgenus have been described in the pupal stage. For these Edwards (1941: 412) notes the following features: All cephalothoracic setae inconspicuous; seta 11 of metanotum double; setae K and S about equally long and simple; T also simple but shorter; paddle seta somewhat stronger than usual, and accessory seta present.

The pupa of the single species recorded from New Guinea is unknown.

#### Subgenus *LOPHOCERAOMYIA* Theobald

**DIAGNOSIS.**—The pupae of the two species recorded from New Guinea agree in the following features: Trumpets fairly long, with well-developed tracheoid portion. Seta C with more than six branches on segments II and III; seta 2 on segment II long and simple, the most conspicuous seta on the segment; setae A-VII and A-VIII, the only plumose tufts on the abdomen.

#### Key to Species of *Culex* (*Lophoceraomyia*)

Seta B on segments IV through VII less than the length of the following segment; seta 1 on segments III through VI a branched tuft (Fig. 49).....*C. fraudatrix*

Seta B on segments IV through VI much longer than the following segment; seta 1 on segments III through VI usually simple, never more than two-branched (Fig. 50).....*C. uniformis*

#### *Culex* (*Lophoceraomyia*) *fraudatrix* (Theobald) 1905

Fig. 49

**CEPHALOTHORAX.** — *Postocular*: 1 small, three- to six-forked; 2 medium, two- to four-forked; 3 medium, three- or four-forked, rarely five-forked.

*Anterothoracic*: 4 medium, three- or four-forked, rarely five-forked; 5 medium, simple or two-forked, rarely three-forked; 6 small, simple or two-forked, rarely three-forked; 7 medium, two-forked or occasionally three-forked.

*Dorsal*: 8 medium, one-half length of trumpet, two-forked.

*Supra-alar*: 9 small, simple or two-forked, rarely three-forked.

*Metanotum*: 10 medium, two-forked or rarely simple; 11 medium, two-forked or rarely simple; 12 medium, two- to four-forked.

*Trumpet*: Long, narrow, length about twelve times the greatest diameter of the meatus; tracheoid area fairly well developed, dark; pinna short, less than one-eighth of the total length of the trumpet.

**ABDOMEN.**—*Segment I*: H small, simple; K long, two-branched; L very small, two-forked;

M small, four- to seven-forked near base, rarely three-forked; S long, simple; T long, two-forked near base or occasionally three-forked; U small, simple.

*Segment II:* A small, simple spine; B long, two-forked near base; C medium, six- or seven-forked near base, rarely with each branch double so that it appears to be twelve-forked; C' small, simple, laterad of B in position; 1 medium, two-forked or occasionally three-forked; 2 very long, simple; 3 small, three-forked, or occasionally four- or five-forked; 4 medium, four-forked or occasionally three-forked; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B long, two-

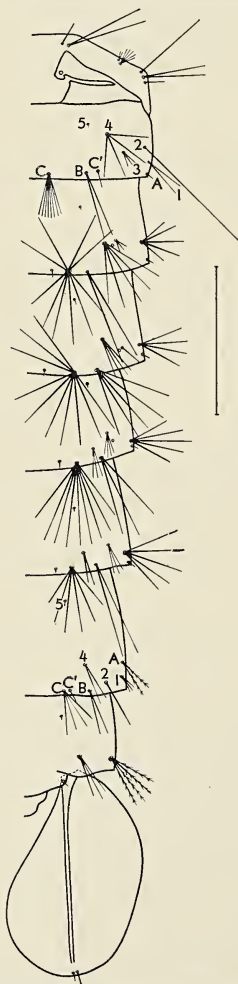


FIG. 49. *Culex fraudatrix*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

branched, rarely simple or three-branched; C long, nine-branched, or rarely seven- or ten-branched; 1 medium, three- to five-forked near base, rarely two-forked; 2 small, three-forked or occasionally simple or two-forked; 3 represented only by its socket; 4 long, five-forked or occasionally four-forked.

*Segment IV:* A small, simple spine; B long, five- or six-branched, rarely four-branched; C long, seven- to ten-branched; 1 medium, four- or five-forked near base, occasionally two- or three-forked; 2 small, two-forked or simple; 3 represented only by its socket; 4 medium, four- or five-forked near base, rarely six-forked.

*Segment V:* A small, simple spine; B long, two- or three-branched, rarely four-branched; C long, seven-branched or occasionally from five- to nine-branched; 1 medium, five- or four-forked near base, occasionally three-forked; 2 small, three- to six-forked near base; 3 represented only by its socket; 4 medium, three- or two-forked near base.

*Segment VI:* A small, simple spine; B long, two-branched or occasionally three-branched; C medium, four- to six-forked near base, occasionally two- or three-forked; 1 medium, four- or five-forked near base, rarely three-forked; 2 small, three-forked, occasionally simple or two- to four-forked; 3 absent; 4 small, two-forked or occasionally simple.

*Segment VII:* A medium, three-branched, plumose, occasionally two- or four-branched; B medium, two-forked or occasionally simple; C medium, four- to six-forked or rarely three-forked; 1 small, two- or three-forked; 2 medium, simple or rarely two-forked; 4 medium, three- or four-forked or rarely two-forked.

*Segment VIII:* A medium, four- or five-branched, plumose, occasionally six- or seven-branched; A' medium, two- or three-forked near base.

*Segment IX:* v small, simple spine.

*Paddle:* Elongate oval; margin smooth; midrib dividing the paddle unequally, the lateral face a little wider than the medial face; terminal seta small, simple; accessory seta a little longer, simple.



SPECIMENS EXAMINED.—The pupal exuviae of five females from Gamadodo, WagaWaga, and Hilimoi, Milne Bay, Papua.

*Culex (Lophoceraomyia) uniformis*  
Theobald 1905

Fig. 50

CEPHALOTHORAX. — *Postocular*: 1 small, three- to five-forked; 2 small, two- to four-forked; 3 medium, simple.

*Anterothoracic*: 4 long, stout, two-forked; 5 medium, two-forked or simple; 6 small, simple; 7 medium, two-forked.

*Dorsal*: 8 medium, one-half length of trumpet, two- to four-forked.

*Supra-alar*: 9 medium, simple or two-forked.

*Metanotum*: 10 small, three-forked or rarely two- or four-forked; 11 medium, simple; 12 small, three-forked or rarely simple.

*Trumpet*: Long, length nine to ten times greatest diameter of meatus; pinna short, one-fifth to one-sixth of total length of trumpet; tracheoid area fairly well developed, dark pigmented.

ABDOMEN.—*Segment I*: H small, simple; K long, simple; L small, two-forked near apex or rarely three-forked; M small, five-forked near base or occasionally three- or four-forked; S very long, simple; T long, simple; U small, two-forked near base or simple.

*Segment II*: A small, simple spine; B medium, simple; C medium, nine- to eleven-forked near basal one-fifth; C' small, simple, lateral and anterior to B in position; 1 long, simple; 2 very long, simple, rarely three-forked at apex; 3 small, three- to four-forked; 4 small, three- or four-forked or rarely two-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple, very close to C in position; C medium, seven- or eight-branched, rarely ten-branched; C' small, simple, mesad of C on this and all following segments; 1 long, simple or occasionally two-forked; 2 small, simple or occasionally two- or three-forked; 3 represented only by its socket on this and segments IV and V; 4 small, four-branched, or rarely six-branched.

*Segment IV*: A small, simple spine; B very long, nearly reaching posterior margin of segment VI, two-branched, plumose; C long, usually four-branched, range from two to six; 1 long, simple or occasionally two-forked; 2 small, simple or rarely two-forked; 4 medium, three- to seven-forked.

*Segment V*: A small, simple spine; B very long, plumose, two-branched; C medium, two- or three-forked; 1 long, two-forked or simple; 2 small, three- or four-forked, rarely five-forked; 4 medium, two-forked or rarely three-forked.

*Segment VI*: A small, simple spine; B very long,

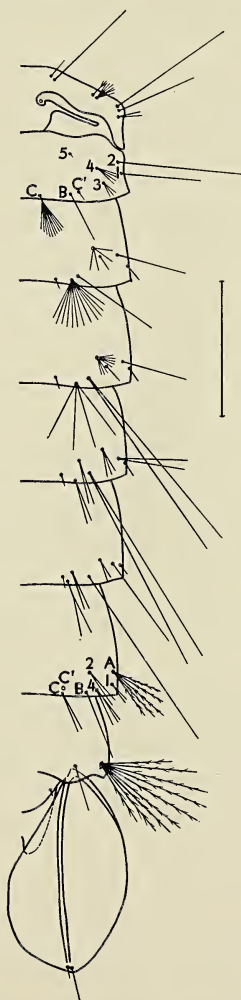


FIG. 50. *Culex uniformis*: dorsal aspect of right half of abdomen of male from Mios Woendi, Dutch New Guinea.

plumose, simple or rarely three-forked near apex; C long, two-forked near basal one-third; 1 long, simple or rarely two-forked; 2 small, three- or two-forked; 3 absent; 4 medium, two-forked or occasionally simple or three-forked.

*Segment VII:* A fairly long, plumose, four- or five-branched, rarely three-branched; B fairly long, simple or rarely two-branched; C medium, two-forked or occasionally simple; 1 small, two-forked or occasionally simple; 2 medium, simple or two- to three-forked; 4 medium, two-forked or rarely simple.

*Segment VIII:* A large, conspicuous, plumose, six- to nine-branched, most frequently nine-branched; A' medium, simple or two-forked.

*Segment IX:* v small, simple spine.

*Paddle:* Elongate oval; margin smooth; a little black pigment near base of paddle on one specimen; midrib dividing paddle almost equally; terminal seta small, simple; accessory seta medium, simple or occasionally two-forked at apex.

**SPECIMENS EXAMINED.**—The pupae of seven males and two females from Mios Woendi, Dutch New Guinea. It should be recorded that although a representative number of larvae of this species was collected on several occasions we were not successful in rearing any imagines. It is possible that although the larvae agree fairly well with the brief description published by Barraud (1934) this may be an undescribed species.

#### Subgenus *CULICIOMYIA* Theobald

**DIAGNOSIS.**—The three New Guinean species of which the pupae are known agree in the following respects: Seta C-II a multibranched short tuft of fifteen or more branches; at least setae B-IV-VI plumose.

#### Key to Species of *Culex* (*Culiciomyia*)

1. Setae B-IV-VI exceeding posterior margins of following segments; setae C-III-VI never plumose (Fig. 51).....*C. fragilis*  
 Setae B-IV-VI never exceeding posterior margins of following segments; setae C-III-VI always plumose..... 2

2. Setae K and B-II plumose; seta 1 on segment VI not plumose (Fig. 52).....  
 ..... *C. papuensis*  
 Setae K and B-II not plumose; seta 1 on segment VI plumose (Fig. 53).....  
 ..... *C. pullus*

*Culex* (*Culiciomyia*) *fragilis* Ludlow 1903

#### Fig. 51

**CEPHALOTHORAX.**—*Postocular:* 1 medium, three- or four-forked; 2 medium, two- to four-forked; 3 medium, two-forked or rarely three-forked.

*Anterothoracic:* 4 long, three- or four-forked, rarely two-forked; 5 medium, two-forked, rarely simple; 6 small, simple or two-forked; 7 long, two-forked or occasionally simple.

*Dorsal:* 8 long, one-half length of trumpet, two- or three-forked.

*Supra-alar:* 9 long, simple or two-forked.

*Metanotum:* 10 medium, six- to ten-forked; 11 medium, two-forked or simple; 12 medium, two- to four-forked.

*Trumpet:* Funnel-shaped, length equal to a little more than four times the greatest diameter of meatus; pinna long, a little less than one-third of the total length; tracheoid portion dark-pigmented, remainder of trumpet lightly pigmented.

**ABDOMEN.**—*Segment I:* H small, simple; K medium, two-forked or occasionally simple; L small, two- or three-forked near middle, rarely five-forked; M small, three- or four-forked near base, occasionally simple; S long, simple; T long, simple or two-forked; U small, simple.

*Segment II:* A small, simple; B medium, two-forked near middle or rarely simple; C medium, twenty- to twenty-five-branched; C' small, simple spine on this and all following segments; 1 medium, simple or occasionally two-forked; 2 long, simple or two-forked; 3 small, simple, rarely two- or three-forked near middle; 4 medium, usually four-branched, occasionally two- or three-branched; 5 minute, simple on this and all following segments.



*Segment III*: A small, simple; B medium, two-forked near middle; C medium, three- or four-branched, occasionally two- or five-branched; 1 medium, two-forked or rarely simple; 2 small, two- or three-forked at base; 3 represented only by its socket on this and segments IV and V; 4 medium, usually four-branched, occasionally five- or three-branched.

*Segment IV*: A small, simple; B long, two- or three-branched, slightly plumose apically; C medium, three-branched, occasionally four- or five-branched; 1 medium, two- or three-forked, rarely simple; 2 small, two-forked, rarely simple; 4

small, three- or four-forked near basal one-third, rarely simple.

*Segment V*: A small, simple; B long, two-branched, slightly plumose apically; C medium, three- or four-branched, occasionally two- or five-branched; 1 medium, two- or three-forked; 2 small, usually three- or four-forked, rarely two- or five-forked; 4 medium, two-forked near base or occasionally simple.

*Segment VI*: A small, simple; B long, two-branched, slightly plumose apically; C long, two- or three-branched; 1 medium, two-forked near base, rarely simple; 2 small, two- to four-forked, rarely simple; 3 absent; 4 medium, simple or two-forked.

*Segment VII*: A medium, stout, plumose, three- or four-branched, rarely five-branched; B medium, simple or rarely two-forked; C medium, simple to three-branched, rarely four-branched; 1 small, usually three-forked, occasionally four-forked; 2 medium, two-forked; 4 small, two-forked or occasionally simple.

*Segment VIII*: A medium, stout, plumose, five- or six-branched, rarely four-branched; A' medium, simple or two-forked.

*Segment IX*: v small, simple spine.

*Paddle*: Large, long, broadest at about apical one-third; margin smooth; midrib strong, dividing paddle unequally, the lateral face slightly wider than medial face; terminal seta small, stout, two-branched or simple; accessory seta small, simple.

**SPECIMENS EXAMINED**.—The pupal exuviae of eight males and eight females from Gama-dodo and Hilimoi, Milne Bay, Papua, and Draeger Harbor, Northeast New Guinea.

*Culex (Culiciomyia) papuensis* (Taylor)  
1914

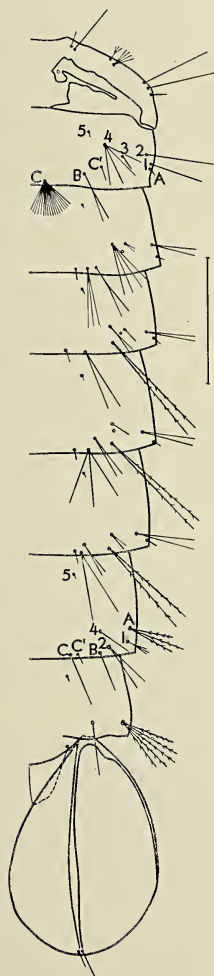


FIG. 51. *Culex fragilis*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.

Fig. 52

**CEPHALOTHORAX**. — *Postocular*: 1 small, two-branched, occasionally more; 2 medium, two- or three-branched; 3 medium, three-branched or simple.

*Anterothoracic*: 4 medium, five- or six-branched, rarely simple or two-branched, plumose; 5 small, two- to four-forked; 6 small, two- or three-forked, rarely simple; 7 medium, two-forked.

*Dorsal*: 8 medium, one-half length of trumpet, two- or three-branched.

*Supra-alar*: 9 small, two-forked.

*Metanotum*: 10 medium, five-forked, plumose; 11 medium, two-forked or occasionally simple, plumose; 12 medium, two-forked and plumose.

*Trumpet*: Length five or six times the greatest diameter of the meatus; pinna about one-fourth of the total length of trumpet; tracheoid portion darkly pigmented.

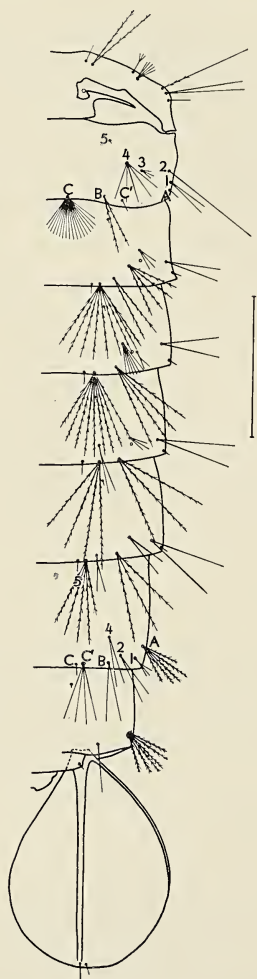


FIG. 52. *Culex papuensis*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

**ABDOMEN.**—*Segment I*: H small, simple; K long, two-branched or simple, plumose; L small, simple or two- to three-forked near apex; M small, three- or four-forked near base, rarely five-forked; S long, simple; T medium, two-forked; U small, simple.

*Segment II*: A small, simple spine; B long, two-branched or occasionally simple, plumose; C medium, twenty-five- to thirty-branched tuft; C' small, simple on this and all following segments; 1 medium, two-forked or simple; 2 long, simple; 3 small, two- to four-forked; 4 medium, four- to five-branched, occasionally simple or two-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, two-branched or occasionally simple or three-branched, plumose; C long, five- to twelve-branched, plumose; 1 medium, simple or two-branched; 2 small, two- to four-forked; 3 represented only by its socket on this and segments IV and V; 4 long, two-branched or occasionally four-branched, plumose.

*Segment IV*: A small, simple spine; B long, two-branched, occasionally four- or five-branched, plumose; C long, two- or four-branched, rarely eight- or nine-branched, plumose; 1 medium, two-branched or simple; 2 small, two-forked near basal one-third or occasionally simple; 4 medium, four- to six-branched.

*Segment V*: A small, simple spine; B long, two- to three-branched, plumose; C long, two- to four-branched, plumose; 1 long, simple or occasionally two-branched; 2 small, two- to four-branched; 4 medium, two-forked near basal one-third or rarely simple.

*Segment VI*: A small, simple spine; B long, simple or two- to three-branched, plumose; C long, three- to six-branched, plumose; 1 long, two-branched or occasionally simple; 2 medium, two-forked or occasionally simple; 3 absent; 4 medium, two-forked near middle or rarely simple.

*Segment VII*: A medium, four- to six-branched, plumose; B medium, simple or occasionally two-branched; C medium, four-branched or occasion-



ally two-branched; 1 small, four-forked near middle or rarely three-forked; 2 medium, simple or two-branched; 4 medium, two-forked.

*Segment VIII*: A medium, stout, six- to ten-branched, plumose; A' medium, simple or two-forked near middle.

*Segment IX*: v small, simple spine.

*Paddle*: Elongate oval shaped, length roughly about one-fourth greater than width; margin smooth; midrib strong, reaching apex; terminal seta short, simple; accessory seta short, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of four males and three females from Gamadodo and Hilimoi, Milne Bay, Papua.

*Culex* (*Culiciomyia*) *pullus* Theobald 1905

Fig. 53

Pupa heretofore undescribed, although Hill (1925: 74) included figures of the paddles and trumpet of specimens from Rabaul, New Britain.

**CEPHALOTHORAX.**—*Postocular*: 1 medium, four- or three-branched; 2 medium, two-branched; 3 medium, three-branched or occasionally two-branched.

*Anterothoracic*: 4 medium, three- or four-branched, rarely five- or six-branched; 5 small, two- or three-forked; 6 small, simple or two-forked; 7 medium, two- or three-forked.

*Dorsal*: 8 medium, one-half length of the trumpet, two-branched or occasionally four-branched.

*Supra-alar*: 9 medium, two-branched.

*Metanotum*: 10 medium, five- to eight-branched, plumose; 11 medium, two-forked near base, rarely four-forked, plumose; 12 medium, two- to four-forked.

*Trumpet*: Length equal to five or six times the greatest diameter of the meatus; pinna short, roughly equal to the greatest diameter of the meatus; tracheoid portion darkly pigmented.

**ABDOMEN.**—*Segment I*: H small, stout, simple or rarely two-forked near apex; K long, two-branched; L small, two- to six-forked; M small, four- to six-forked; S long, simple; T long, two-forked near base; U small, simple or rarely two-forked.

*Segment II*: A small, simple spine; B long, two-forked near base or occasionally simple; C medium, fifteen- to twenty-branched tuft; C' small, simple on this and all following segments; 1 medium, two-forked near base or occasionally three-forked or simple; 2 long, simple; 3 small, three-forked or rarely simple or two-forked; 4 medium, four- or five-forked, rarely two- or three-forked; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, two-forked near base, plumose; C long, six- or seven-branched, only occasionally five- or nine-branched, plumose; 1 medium, two-forked or

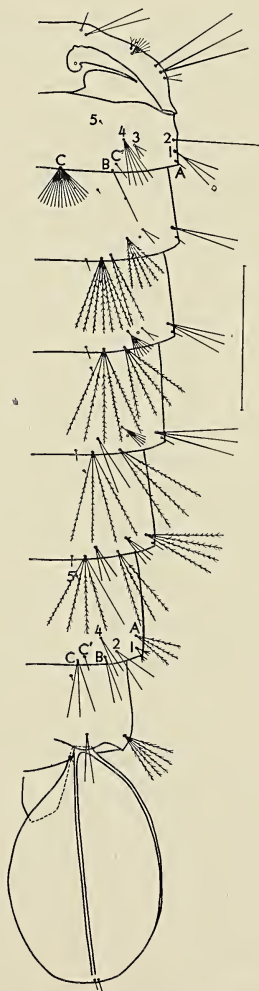


FIG. 53. *Culex pullus*: dorsal aspect of right half of abdomen of male from Hilimoi, Papua.

occasionally simple; 2 small, three- or four-forked; 3 represented only by its socket on this and segments IV and V; 4 medium, three- to five-branched, plumose.

*Segment IV:* A small, simple spine; B long, four-branched or occasionally three-branched, plumose; C long, five- or four-branched, rarely three- or six-branched, plumose; 1 medium, two-forked, rarely three-forked; 2 small, two-forked near middle, rarely four-forked; 4 small, five- to seven-forked near basal one-third.

*Segment V:* A small, simple spine; B long, three-branched or occasionally two-branched, plumose; C long, four-branched or rarely three-branched, plumose; 1 long, two-branched, or occasionally three-branched; 2 small, two- to six-forked near basal one-third; 4 medium, two-forked or rarely simple.

*Segment VI:* A small, simple spine; B long, two- or three-branched, rarely four-branched, plumose; C long, four-branched, rarely three- to six-branched, plumose; 1 long, two- or three-branched, rarely four-branched, plumose; 2 small, two- or three-forked, rarely simple; 3 absent; 4 small, two-forked or occasionally three-forked.

*Segment VII:* A medium, three- or four-branched, plumose; B medium, two-branched or occasionally three-branched; C medium, three- or four-branched; 1 small, four- or five-branched; 2 medium, two-forked or occasionally simple; 4 medium, two-forked.

*Segment VIII:* A medium, stout, usually five-branched, occasionally six- or eleven-branched, plumose; A' medium, two-forked near base or rarely simple.

*Segment IX:* v small, simple spine.

*Paddle:* Elongate oval shaped, length nearly one-third greater than width; margin rounded, smooth; midrib strong, reaching apex, dividing the paddle almost equally although the lateral face is slightly wider than the medial face; terminal seta small, simple or two-branched; accessory seta small, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of nine males and eleven females from Gama-

dodo, WagaWaga, and Hilimoi, Milne Bay, Papua, and Draeger Harbor, Northeast New Guinea.

Subgenus *ACALLYNTRUM* Stone and Penn

**DIAGNOSIS.**—The pupae of the two New Guinean species of *Acallyntrum* are distinct from those of all other *Culex* of the island in the absence of both the terminal and accessory paddle setae.

Key to Species of *Culex* (*Acallyntrum*)

Lateral margins of paddles finely serrate; only the larger setae of segments III to VII plumose, all other setae non-plumose (Fig. 54) ..... *C. bicki*  
Lateral margins of paddles smoothly rounded, not serrate; nearly all of the dorsal abdominal setae finely plumose (Fig. 55) ..... *C. binigrolineatus*

*Culex* (*Acallyntrum*) *bicki* Stone and Penn 1947

Fig. 54

This pupa was described and figured by Stone and Penn (1947: 89). The following description is taken from this paper with additional unpublished notes on the species.

**CEPHALOTHORAX.** — *Postocular:* 2 prominent, plumose, three- or four-branched.

*Metanotum:* 10 usually three-branched; 11 long, simple; 12 usually three-branched.

**ABDOMEN.**—*Segment I:* H small, simple; K long, simple; L small, four-forked near middle; M small, six-forked near base; s long, simple; T long, two-branched; U small, simple.

*Segment II:* A small, simple spine; B medium, simple; C small, six- or seven-branched; C' small, simple on this and all following segments; 1 medium, two-branched; 2 long, simple; 3 small, simple; 4 small, three-forked near base; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B long, simple; C medium, three-branched; 1 medium, simple; 2 small, two-branched; 3 represented only by its socket on this and segments IV and V; 4 small, three-branched.



*Segment IV*: A small, simple spine; B very long, two-branched, plumose; C long, six-branched; 1 medium, two-forked; 2 small, four-forked; 4 medium, four-forked near middle.

*Segment V*: A small, simple spine; B very long, two-branched, plumose; C long, three-branched; 1 medium, two-forked; 2 small, six-branched; 4 medium, two-forked near apex.

*Segment VI*: A small, simple; B very long, two-branched, plumose; C long, four-branched; 1 medium, two-branched; 2 small, three-forked; 3 absent; 4 small, two-forked.

*Segment VII*: A small, five-branched; B small, six-branched; C medium, two-branched; 1 me-

dium, two-forked; 2 long, four-branched, plumose; 4 small, two-forked.

*Segment VIII*: A long, strong, plumose, nine-branched; A' medium, two-forked near middle.

*Segment IX*: v small, simple spine.

*Paddle*: Long, roughly oval; margin finely serrate laterally, apex slightly notched beyond midrib; midrib weak, not reaching apex of paddles; sometimes with an irregular line of black pigment basally on paddle; without terminal setae.

### *Culex (Acallyntrum) binigrolineatus*

Knight and Rozeboom 1945

Fig. 55

The pupa was described and figured by Knight and Rozeboom (1945: 289) from which paper the following description and figure have been taken; additional data were obtained by examination of one of the paratypes.

**CEPHALOTHORAX.** — *Postocular*: 1 small, four-forked near apex; 2 prominent, nearly twice the length of other setae of cephalothorax, three-branched, plumose; 3 medium, three-forked.

*Anterothoracic*: 4 medium, six-forked; 5 small, four-forked; 6 small, two-forked near apex; 7 medium, four-forked near middle.

*Dorsal*: 8 small, two-forked.

*Supra-alar*: 9 medium, two-branched.

*Metanotum*: 10 medium, four-forked near middle; 11 long, simple, plumose; 12 long, four-forked near basal one-fourth.

*Trumpet*: Basal one-third darkly pigmented; tracheoid portion fairly well developed; pinna about one-third length of the trumpet.

**ABDOMEN.**—*Segment I*: H small, simple; K long, simple, stout, plumose; L medium, four-forked near middle; M medium, five-forked near base; S long, two-branched; T long, two-branched; U small, two-forked near apex.

*Segment II*: A small, simple spine; B long, plumose, simple; C small, four-branched; C' small, simple on this and all following segments; 1 medium, three-branched, plumose; 2 medium, two-forked near middle; 3 small, four-forked

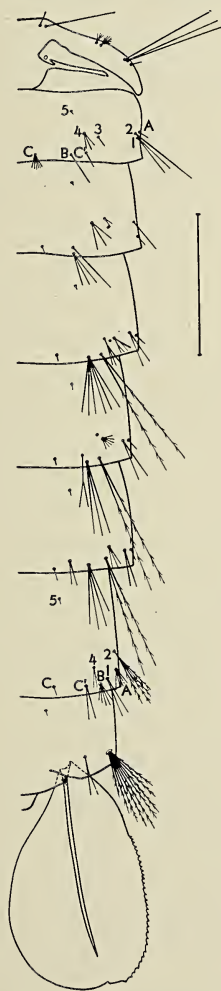


FIG. 54. *Culex bicki*: dorsal aspect of right half of abdomen of female from Hilimoi, Papua.

near middle; 4 medium, three-forked near middle; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, simple, plumose; C medium, simple or rarely two-forked near apex; 1 medium, two-branched; 2 small, three-branched; 3 represented only by its socket on this and segments IV and V; 4 small, two-branched.

*Segment IV*: A small, simple; B long, three- or four-branched, plumose; C medium, two- to four-branched, plumose; 1 medium, three-forked; 2 small, three-forked; 4 small, four-forked.

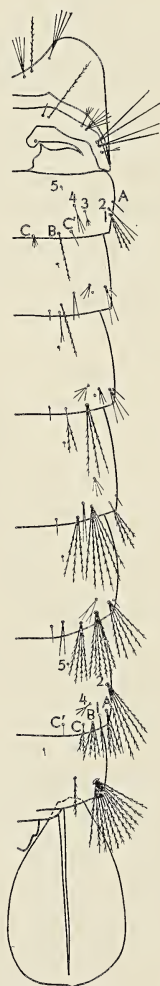


FIG. 55. *Culex binigrolineatus*: dorsal aspect of right half of abdomen of male (after Knight and Rozeboom, 1945).

*Segment V*: A small, simple; B long, three- to five-branched, plumose; C long, two- to four-branched, plumose; 1 medium, three-forked, plumose; 2 small, four-forked; 4 medium, two-branched.

*Segment VI*: A small, simple; B exceedingly well developed, four- to seven-branched, plumose; C long, plumose, simple to four-branched; 1 long, five-branched, plumose; 2 small, four-forked; 3 absent; 4 small, two-branched.

*Segment VII*: A medium, three-branched, plumose; B medium, three- to seven-branched, plumose; C small, two-forked, plumose; 1 medium, simple, plumose; 2 long, five-branched, plumose; 4 small, three-forked.

*Segment VIII*: A strongly developed, fan-like, nine- to fourteen-branched, plumose; A' medium, simple, plumose.

*Paddle*: Long, roughly oval, with apex somewhat drawn out into a point; only basal third of lateral margin buttressed, entire margin smooth; without terminal setae.

#### Subgenus *CULEX* Linnaeus

**DIAGNOSIS.**—The four New Guinean species of this subgenus known in the pupal stage all have seta K on segment I two-forked; seta A on segments II–VI is a small, simple spine set close to the postero-lateral corners of the segments; setae A–VII and A–VIII are fairly well-developed plumose tufts placed some distance anterior to the postero-lateral corners of the segments; setae 4–II and 4–III well-developed tufts placed anterior to and usually between B–II and C'–II, and between B–III and 2–III respectively.

#### Key to Species of *Culex* (*Culex*)

1. Paddles with medial one-half conspicuously brown-pigmented; without accessory seta on paddle (Fig. 56).....*C. squamosus*  
Paddles without brown pigment; accessory seta of paddle present.....2
2. Seta 1 on segments III–VI simple or two-forked, never a well-developed tuft (Fig. 57).....*C. sitiens*  
Seta 1 on segments III–VI a well-developed tuft of three or four branches.....3



3. Seta B-IV a large tuft of five to eight branches; setae C-III-VI six- to fourteen-branched (Fig. 58).....*C. annulirostris*  
 Seta B-IV only two- or three-branched;  
 setae C-III-VI three- or four-branched....  
 .....*C. fatigans*

*Culex (Culex) squamosus* (Taylor) 1914  
 Fig. 56

DIAGNOSIS.—Readily separated from all other New Guinean species of *Culex* in having the medial one-half of the paddle pigmented a dark brown.

CEPHALOTHORAX. — *Postocular*: 1 small, three- or four-forked; 2 small, three-forked; 3 medium, two- to five-forked.

*Anterothoracic*: 4 medium, three- to five-forked; 5 medium, two- to four-forked; 6 small, two-forked or occasionally three-forked; 7 medium, two-forked or simple.

*Dorsal*: 8 medium, one-third length of trumpet, four-branched or occasionally three-branched.

*Supra-alar*: 9 small, three-forked.

*Metanotum*: 10 long, eight-branched; 11 medium, two-forked; 12 small, three- or four-forked.

*Trumpet*: Fairly long, length about three times the greatest diameter of the meatus; tip greatly expanded, pinna about one-third the length of the trumpet; tracheoid portion fairly well developed, dark pigmented.

ABDOMEN.—*Segment I*: H small, simple; K medium, two-forked near base or rarely three-forked; L very small, three-forked near apex or occasionally two-forked; M very small, five- to eight-forked near base; S long, simple; T medium, two- or three-forked; U small, simple.

*Segment II*: A small, simple spine; B medium, two-branched; C small, four- to seven-branched; C' small, simple, laterad of B in position; 1 medium, two-branched or simple; 2 medium, two-branched or simple; 3 small, two- to five-forked; 4 medium, three-branched, rarely these branches may all be doubled so that seta appears to be six-branched; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B medium, two-branched; C long, plumose, five- to eight-

branched; C' small, simple spine on this and all following segments; 1 medium, simple; 2 small, two- to five-forked near base; 3 represented only by its socket on this and segments IV and V; 4 medium, four- or five-forked near base.

*Segment IV*: A small, simple spine; B long, plumose, three-branched; C long, plumose, three-branched or occasionally four- or five-branched; 1 medium, simple; 2 very small, two-forked; 4 small, five-forked or occasionally four-forked.

*Segment V*: A small, simple spine; B long, plumose, two- or three-branched; 1 medium, simple; 2 small, five- to seven-forked near base; 4 medium, two-forked or simple.

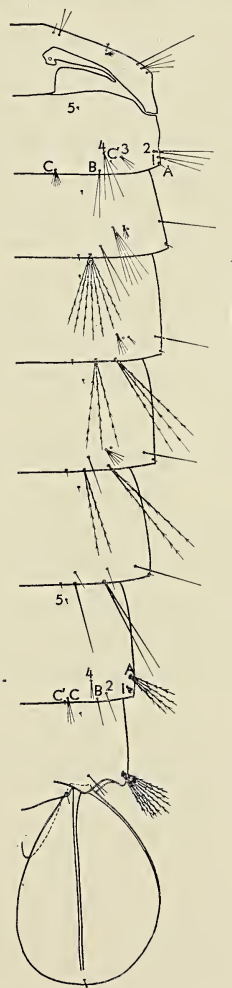


FIG. 56. *Culex squamosus*: dorsal aspect of right half of abdomen of male from Gamadodo, Papua.

*Segment VI*: A small, simple spine; B long, two-branched; C long, simple or occasionally two-branched; 1 long, simple; 2 small, simple to four-forked; 3 absent; 4 small, simple or two-forked.

*Segment VII*: A medium length, stout, plumose, three- to five-branched; B small, simple or occasionally two-branched; C small, two-branched or occasionally three-branched; 1 very small, three- to five-branched; 2 small, simple to four-forked; 4 small, two-forked.

*Segment VIII*: A medium length, stout, plumose, five- to eight-branched, usually six-branched; A' small, two-forked near middle.

*Segment IX*: v small, stout, simple spine.

*Paddle*: Elongate oval; margin smooth; midrib dividing the paddle unequally, the lateral face a little wider than the medial face; medial face entirely dark-brown pigmented, the brown pigment extending somewhat less intensely into the apical third of the lateral face; terminal seta small, simple or rarely two-forked at apex; accessory seta absent.

**SPECIMENS EXAMINED.**—The pupal exuviae of eight males and four females from Gama-dodo, WagaWaga, and KanaKope, Milne Bay, Papua.

*Culex (Culex) sitiens* Wiedemann 1828

Fig. 57

Pupa partially described without figures by Edwards (1941: 417) and Taylor (1943: 99); Hill (1925: 73) and Buxton and Hopkins (1927: 79) included figures of the paddles and trumpets without accompanying descriptions.

**CEPHALOTHORAX.**—*Postocular*: 1 medium, three- to five-forked; 2 medium, two-forked; 3 long, two-forked.

*Anterothoracic*: 4 long, three-forked or occasionally two-forked; 5 medium, two- or three-forked; 6 small, three-forked or occasionally simple or two-forked; 7 medium, two-forked or occasionally three-forked.

*Dorsal*: 8 long, half length of trumpet, two-branched.

*Supra-alar*: 9 long, two-branched.

*Metanotum*: 10 long, plumose, five-branched or occasionally two- to four-branched; 11 long, plumose, two-forked; 12 long, three-forked or occasionally two-forked.

*Trumpet*: Fairly long, length about five times greatest diameter of meatus; tracheoid portion fairly well developed, dark-pigmented; pinna long, about one-third of total length of trumpet.

**ABDOMEN.**—*Segment 1*: H small, simple; K long, two-forked near base; L small, two-forked near base or occasionally simple or three-forked; M small, five- or six-forked near base; S long,

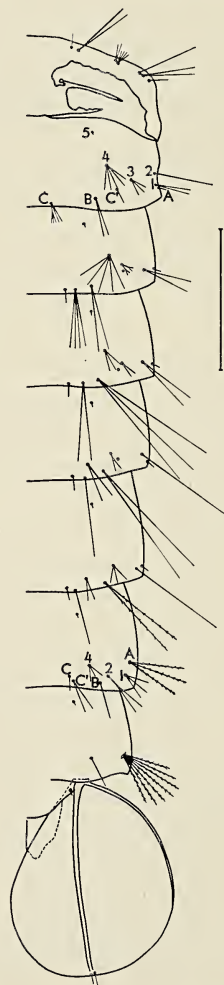


FIG. 57. *Culex sitiens*: dorsal aspect of right half of abdomen of male from Amsterdam Island, Dutch New Guinea.



simple or occasionally two-forked; T long, simple or rarely three-forked near apex; U small, simple.

*Segment II:* A small, simple spine; B medium, two-branched; C small, four- to seven-forked; C' small, simple, laterad of B in position; 1 medium, simple or two-forked; 2 long, two-forked near base or occasionally simple; 3 medium, four- or three-forked; 4 medium, five-forked or occasionally three-forked; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B long, two-branched; C long, three- or four-branched; C' small, simple, placed mesad of C on this and all following segments; 1 medium, two-forked or occasionally simple; 2 small, three- to five-forked; 3 represented only by its socket on this and segments IV and V; 4 medium, five-forked or occasionally four-forked.

*Segment IV:* A small, simple spine; B very long, exceeding posterior margin of segment V, three-branched; C long, two-branched or occasionally three- to four-branched; 1 medium, two-forked or occasionally simple; 2 small, simple or occasionally two- or three-forked; 4 small, three- to five-forked.

*Segment V:* A small, simple spine; B very long, exceeding posterior margin of segment VI, two-branched; C long, simple or two-branched; 1 very long, simple; 2 small, two- to four-forked near middle; 4 medium, two- or three-forked near base.

*Segment VI:* A small, simple spine; B long, slightly plumose, two-branched; C long, simple or two-branched; 1 long, simple; 2 small, two- to four-forked; 3 absent; 4 small, two-forked.

*Segment VII:* A fairly long, stout, plumose, three-branched or occasionally four-branched; B medium, simple; C medium, two-branched; 1 small, three-forked or rarely simple or four-forked; 2 medium, two-forked or occasionally three-forked; 4 small, three-forked or occasionally simple or two-forked.

*Segment VIII:* A fairly long, stout, plumose, eight-branched or occasionally three-branched; A' medium, simple or two-forked.

*Segment IX:* v very small, simple spine on only 30 per cent of the specimens examined.

*Paddle:* Rounded, length not greatly exceeding width as in other species of the subgenus *Culex*; margin smooth; midrib dividing the paddle unequally, the lateral face a little wider than medial face; terminal seta small, simple; accessory seta small, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of 25 males and 16 females from Hilimoi and KanaKope, Milne Bay, Papua, and Amsterdam Island, Dutch New Guinea.

*Culex (Culex) annuli-rostris* Skuse 1889

Fig. 58

Pupa heretofore undescribed, although Buxton and Hopkins (1925: 79) included it in a key to the *Culex* pupae of Samoa and the New Hebrides and gave a figure of the trumpet.

**CEPHALOTHORAX.**—*Postocular:* 1 medium, four- or five-branched; 2 medium, four-branched, range from two- to five-branched; 3 medium, four-branched, range from two to five.

*Anterotheracic:* 4 medium, five-branched, range from two to six; 5 small, four- or three-forked; 6 small, three-branched, occasionally two- or four-branched; 7 medium, two-branched.

*Dorsal:* 8 long, over one-half the length of trumpet, two- to five-branched.

*Supra-alar:* 9 small, two- to five-branched.

*Metanotum:* 10 medium, ten- to twelve-branched, occasionally seven- to nine- branched; 11 medium, plumose, two-forked or occasionally three-forked; 12 medium, usually three-forked, range from two to six.

*Trumpet:* Fairly long, length about five times greatest diameter of the meatus; tracheoid portion fairly well developed, dark pigmented; pinna a little more than one-fourth of the total length.

**ABDOMEN.**—*Segment I:* H small, simple; K long, two-forked near base, plumose; L small, six- to eight-forked near middle, occasionally three- to five-forked; M small, seven- to eleven-branched; S very long, simple; T long, two-

forked near base or rarely three-forked; U small, simple.

*Segment II:* A small, simple spine; B medium, two-branched or rarely three-branched; C medium, six- to fourteen-branched; C' small, simple, laterad of B in position; 1 medium, two-forked or rarely simple; 2 long, simple; 3 small, five- or six-forked, rarely seven-forked; 4 medium, eight- to ten-forked near base, occasionally five- or six-forked; 5 minute, simple on this and all following segments.

*Segment III:* A small, simple spine; B long, plumose, two-branched or forked near middle; C

long, plumose, ten- to fifteen-branched, rarely less; C' small, simple on this and all following segments mesad of C in position; 1 long, three- or four-branched; 2 small, two- or three-forked at apex, rarely five- to seven-forked; 3 represented only by its socket on this and segments IV and V; 4 medium, six- to eleven-forked near base.

*Segment IV:* A small, simple spine; B long, plumose, five- to eight-branched, rarely less; C long, plumose, five- to ten-branched, usually eight or nine; 1 long, four-forked near base, rarely three- or five-forked; 2 small, simple or occasionally two- to five-forked near middle; 4 medium, six-forked near base, rarely five- to eight-forked.

*Segment V:* A small, simple spine; B long, plumose, two- or three-branched; C long, plumose, seven- to nine-branched, rarely less; 1 long, five- or six-branched; 2 medium, seven-branched, range from three to nine; 4 medium, three- or four-forked near base, rarely two-forked or simple.

*Segment VI:* A small, simple spine; B very long, plumose, two-branched or rarely three-branched; C long, plumose, four- to eight-branched, rarely less; 1 long, six-branched, rarely five-branched or less; 2 medium, three- to five-forked; 3 absent; 4 medium, two- or three-forked.

*Segment VII:* A long, plumose, four- or five-branched; B fairly long, two-branched; C fairly long, four- or five-branched usually, range from two to six; 1 small, five- to eight-forked; 2 fairly long, two-forked; 4 medium, four-forked, range from two to five.

*Segment VIII:* A long, stout, plumose, six- to eleven-branched, usually eight-branched; A' long, two- or three-forked near base, rarely four-forked.

*Segment IX:* v small, stout spine.

*Paddle:* Elongate paddle-shaped, widest point at about apical one-fourth; margin smooth, but-tress extending to the widest point; midrib dividing the paddle unequally, the lateral face somewhat wider than medial face; terminal seta small, simple; accessory seta small, simple.

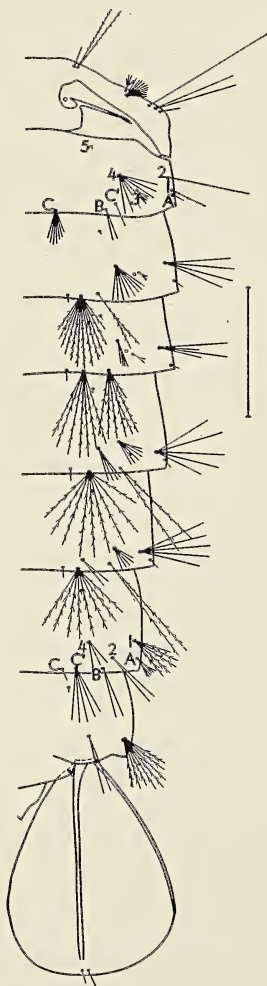


FIG. 58. *Culex annulirostris*: dorsal aspect of right half of abdomen of male from Mios Woendi, Dutch New Guinea.



**SPECIMENS EXAMINED.**—The pupal exuviae of four males and three females from Gamadodo and WagaWaga, Milne Bay, Papua, and Mios Woendi and Amsterdam Island, Dutch New Guinea.

*Culex* (*Culex*) *fatigans* Wiedemann 1828 (=quinquefasciatus Say 1823, of American authors)

The pupa of *C. fatigans* has received considerable attention but a complete description has not previously been published. Among those who have considered *fatigans* pupae to some degree are Banks (1908: 250), Cooling (1924: 9), Buxton and Hopkins (1925: 301; 1927: 83), Edwards (1941: 421), and Taylor (1943: 101).

**CEPHALOTHORAX.**—*Postocular*: 1 long, two- or three-branched; 2 medium, four-branched; 3 long, two-branched.

*Anterothoracic*: 4 long, five-branched; 5 medium, five-branched; 6 medium, two-forked; 7 long, two-forked.

*Dorsal*: 8 long, one-half length of trumpet, three-branched.

*Supra-alar*: 9 medium, two- or three-forked.

*Metanotum*: 10 long, six- or seven-branched; 11 long, two- or three-forked; 12 long, three-forked.

*Trumpet*: Fairly long, length about four times the greatest diameter of the meatus; tracheoid portion fairly well developed, dark-pigmented; pinna long, a little more than one-third of total length of trumpet.

**ABDOMEN.**—*Segment I*: H small, simple; K long, two-forked; L small, two- or three-forked; M small, five-forked; S long, simple; T long, two-forked; U small, simple.

*Segment II*: A small, simple spine; B long, two-branched; C medium, twelve- to fourteen-branched tuft; C' small, simple; 1 very long, two-forked; 2 very long, simple; 3 small, four- or five-forked; 4 medium, three- or four-

branched; 5 minute, simple on this and all following segments.

*Segment III*: A small, simple spine; B long, two-forked; C long, four-branched; C' small, simple on this and all following segments; 1 medium, three-branched; 2 small, five-forked near middle; 3 represented only by its socket on this and segments IV and V; 4 medium, seven-branched.

*Segment IV*: A small, simple spine; B very long, slightly plumose, exceeding the posterior margin of segment V, two- or three-branched; C long, three- or four-branched; 1 medium, four-branched; 2 small, three- or four-forked near middle; 4 small, five- or six-forked.

*Segment V*: A small, simple spine; B very long, exceeding the posterior margin of segment VI, slightly plumose, two-branched; C long, four-branched; 1 long, three-branched; 2 small, two- to four-forked; 4 medium, two-forked.

*Segment VI*: A small, simple spine; B very long, exceeding the posterior margin of segment VII, two-branched or simple; C long, two- or three-branched; 1 long, three- or four-branched; 2 small, three-forked; 3 absent; 4 small, simple or two-forked.

*Segment VII*: A long, stout, plumose, three- to four-branched; B medium, two-branched or simple; C medium, three- or four-branched; 1 small, four- or five-forked; 2 medium, two-forked; 4 medium, two-forked.

*Segment VIII*: A long, stout, plumose, nine-branched; A' medium, two-forked near middle.

*Segment IX*: v small, simple spine.

*Paddle*: Elongate oval; margin smooth; midrib dividing paddle unequally, the lateral face slightly wider than the medial face; one specimen with a slight amount of black pigment at base of paddle; terminal seta small, simple; accessory seta small, simple.

**SPECIMENS EXAMINED.**—The pupal exuviae of five females from Mios Woendi, Dutch New Guinea.

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## Directional Shift of Trade Winds at Honolulu

CHESTER K. WENTWORTH<sup>1</sup>

FOR MANY YEARS it has been known to those persons especially interested in weather conditions that a gradual shift of the direction of prevailing surface wind at Honolulu has been in progress. The data on which such a conclusion can be reached are now sufficient to give a more complete picture of the shift, though they have not been made available in a uniform published form. The present paper has made use of data, partly published and partly unpublished, furnished by the Weather Bureau office at Honolulu. From 1905 to 1922 the weather vane was on the Young Hotel Building, 121 feet above the ground and 26 feet above the roof. Since 1922 the weather vane has been on the Federal Building, 99 feet above the ground and 17 feet above the roof. The former location is about 700 feet northwesterly from the latter and about 300 feet nearer the crest of the Koolau Range. The records show no indication of change due to the difference in location.

The Hawaiian Islands are in a latitude zone dominated by northeasterly trade winds, as shown by the fact that over the past 40 years of record the winds in the northeast and east sectors at Honolulu have averaged about 81 per cent of the total time in hours. Similar conditions are shown at various other stations but it is only at the Honolulu station that the record is of sufficient length and that the data are tabulated in a form which permits detailed presentation.

The shift of the prevailing wind direction was first noted in published form by E. A. Beals in 1927 (The northeast trade winds of the North Pacific. *U. S. Monthly Weather Rev.*

55: 211-221). He showed that a shift from northeast toward east was then in progress. He discussed the possible influence of changes in value and position of high pressure areas north and east of Honolulu, as well as changes in ocean temperature. He concluded that the "true explanation is not at once apparent."

In 1938, in an unpublished manuscript (Wentworth, C. K. *Geology and ground water resources of the Palolo-Waialae district (Honolulu)*. Board of Water Supply, Manuscript Report, 274 pages; p. 29), the writer extended the tabulation by 5-year intervals and showed that the swing from northeast toward east continued until 1930 and appeared to slow down from 1930 to 1934. Since there is no possibility of such a shift being continuous in one direction, it then appeared that a reversal might be imminent. Only recently, in the course of further discussion of climatic data, the percentages of hours of wind in the northeast and east sectors for the years 1935 to 1946 were secured through the courtesy of the Weather Bureau office at Honolulu and the analysis was extended to include the whole period from 1905 to 1946. It is now clearly shown that the anticipated reversal has taken place. The 5-year moving average used as an index had, by 1944, returned from the extreme easterly position more than halfway to the apparent extreme northeasterly position suggested by the data for the period 1907 to 1910 (Fig. 1).

In order that the reader may evaluate the general picture presented here, some explanation of the method of analysis is warranted. The fundamental data consist of a summarized record of wind in each of the eight sectors centered at the four positions of north, west, south, and east, and the four intermediate (45°) posi-

<sup>1</sup>Geologist, Honolulu Board of Water Supply. Manuscript received May 23, 1948.



tions, of which northeast is one. The total of wind in each sector for each month is tabulated both by miles and by hours, and is summarized in the same way for each calendar year.

This study is based on the number of hours shown in the two sectors east and northeast, since these two sectors, or one fourth of the whole wind rose, have accounted, over the 40-year period, for an average of about 81 per cent of the total time. It is evident that there is a strong central tendency in these two sectors, and the shift of trade-wind direction in degrees has been deduced by comparing the changing proportions carried in the two sectors. For example, in the period of 2 or 3 years around 1908, the percentage of northeast wind was about 56, while that of east wind

was only about 24. On the other hand, by about 1935 and for 3 or 4 years before and after, the percentage of northeast wind was only about 22, and that of east wind had increased to 57. The annual percentages are shown graphically in Figure 2.

The annual data are somewhat ragged, suggesting that a number of minor factors are involved, but the general shift is nevertheless clearly shown. In order to smooth out the lesser variations and combine the concentration of wind in the two sectors, the algebraic difference in percentages (east-northeast) for each year has been tabulated and then a 5-year moving average computed. This average has been plotted in Figure 1 with the point of the arrow placed at the middle year of the 5-year period.

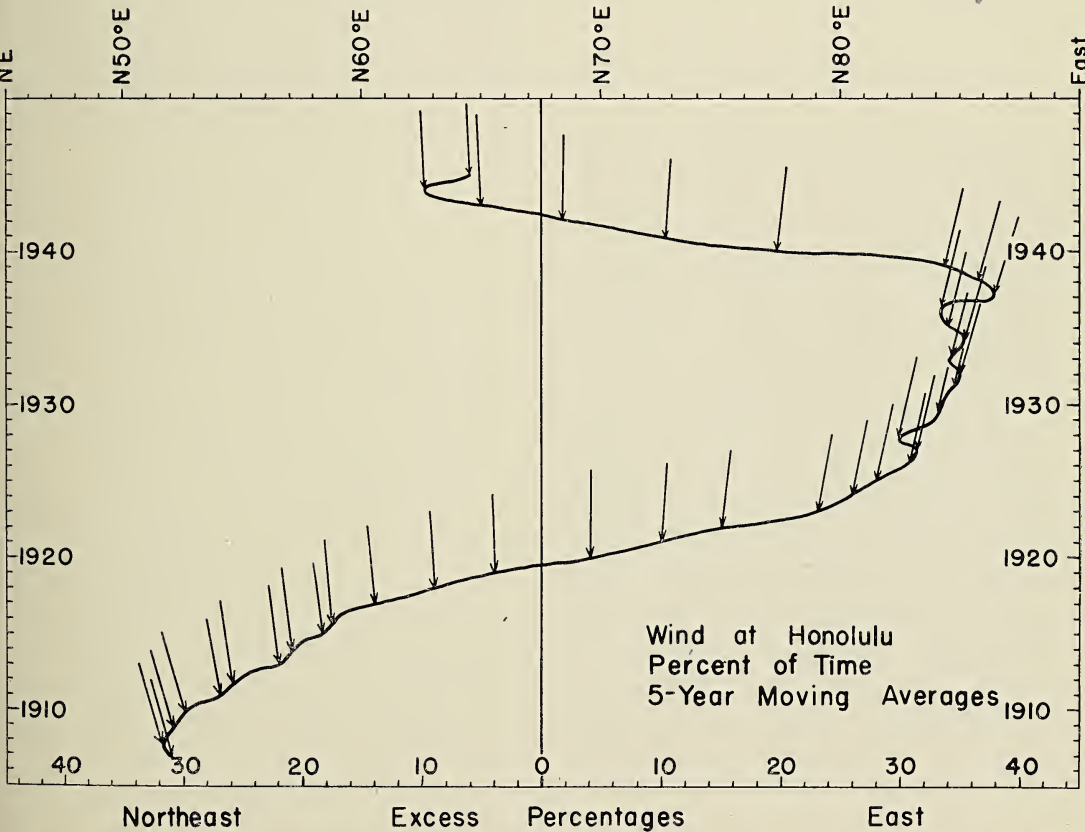


FIG. 1. Diagram showing changing wind directions at Honolulu from 1907 to 1945. Each arrow represents the mean position for 5 years, recorded at the middle year, in terms of the excess of east wind over northeast wind, positive to right, negative to left. The attitudes of the arrows give approximate azimuths, the vertical being N 67.5 E.

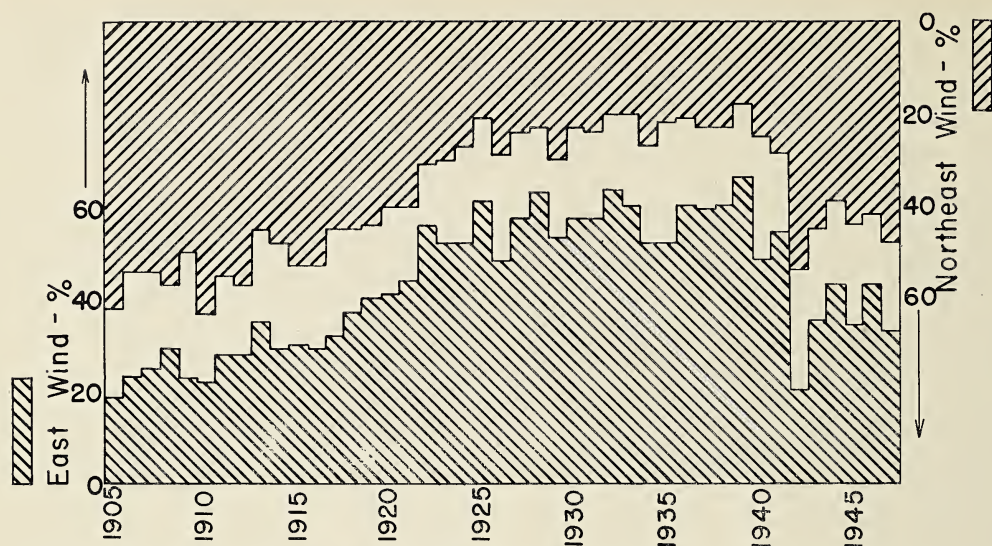


FIG. 2. Graph showing changing proportions of east wind (bottom) and northeast wind (top), by the year, from 1905 to 1947. The residue (blank) of less than 20 per cent includes all other wind directions.

This plotting gives a clear indication of swing but some angular scale is desirable. This has been developed by regarding the proportions of wind in the two major sectors (northeast and east) and in the two adjacent ones (north and southeast) as representing approximately a normal curve of frequency distribution. By very approximate account of the changes in the lesser proportions with the change in the major, it has been developed that 10 units of change in the difference between northeast and east percentages is roughly equivalent to 5 degrees change in direction of the prevailing wind or the central position. For the present purpose, and to give some sense of direction to the graph and the arrows as drawn, this relationship is sufficient, though rigorous calculations or actual measurements through a period of some years would possibly indicate a moderate error in this ratio of comparison and also might show that the ratio is not quite uniform throughout.

The data represented in Figure 1 leave little doubt that a systematic shift is in progress and that it is cyclical in character. At the eastern extreme, the successive positions of arrows also

suggest the swinging of a lesser cycle on the major one, a rather common state of affairs. Since the major cycle is not complete, any estimate that might be made as to period must be very rough. Perhaps we can go no further than to note that the three quarter-periods between the approximate points 1908–1920–1934–1942 are 12, 14, and 8 years, suggesting a whole period of the order of 45 years. No basis is known for such a period and the writer desires only to state roughly the condition that is indicated by the data in Figure 1.

The purpose of this note is to show that there is a definite, rather smooth, cyclical swing which will apparently complete one whole period from 1908 within the 1950 to 1960 decade. To determine its cause will require more knowledge of other cycles than the writer, or perhaps anyone else, now possesses. To determine its true period will of course require a much longer period of record, and the nature of the various wind patterns that enter to produce the frequency distribution could be better analyzed if a more detailed record could be obtained over a number of years.



## Atoll Vegetation and Salinity

F. R. FOSBERG<sup>1</sup>

CORAL ATOLLS are flat rings of reef-rock and calcareous debris usually forming islets with an elevation of only a few feet above sea level. They are distributed throughout the tropical Pacific and Indian Oceans, except the eastern Pacific, with somewhat similar formations in the Atlantic, principally in the Bahama Islands.

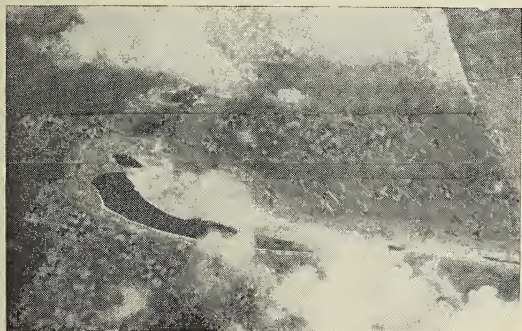


FIG. 1. Northwest corner of Mili Atoll, Marshall Islands, showing a number of small islets. PHOTOGRAPH BY LEONARD E. MASON.

The great Pacific groups of atolls are such archipelagoes as the Tuamotus, Carolines, Marshalls, Gilberts, the Phoenix-Ellice group, and those scattered clusters and individual islands collectively termed the Pacific Equatorial or Line Islands. The observations forming the basis of this paper were made on visits to all these groups, except the Phoenix-Ellice and Gilberts, as well as to the Austral Islands and to the essentially similar barrier reef islets around various high islands.

Atolls are characterized by small floras with few endemic species and a preponderance of widely dispersed strand plants. The plant cover is a strand vegetation which is generally regarded as very uniform and uninteresting. Actually, however, this uniformity exists only in the minds of those who have visited very few

atolls or who have observed them only superficially.

The major differences in vegetation are those between islands in dry and wet climatic belts. The driest atolls, such as Malden, Jarvis, Howland, and Baker, have a sparse desert-like vegetation of a few grasses, herbs, and dwarf shrubs that contrasts strikingly with the luxuriant jungles on atolls in the central and eastern Carolines and southern Marshalls.

Another important difference occurs between the vegetation of small or narrow islets and that of large land areas. The smaller the area of an islet the more extreme is the strand character of its vegetation, and the larger the area the more divergence is shown from this type. This divergence may be of different sorts, as in the



FIG. 2. Outer beach on Nomwin Islet, Hall Island, Caroline Islands, showing scrub vegetation, principally *Scaevola frutescens*. PHOTOGRAPH BY F. R. FOSBERG.

<sup>1</sup>Department of Botany, University of Hawaii. Manuscript received May 11, 1948.



extensive *Lepturus*-*Messerschmidia* savannah on dry Christmas Island, the dense moist forest of Nomwin, the tangled swamp on Ailing-lapalap, or the solid forest of a single species on isolated Vostok Island (*Bishop Mus. Spec. Publ.* 30: 19, 1936).

On most atolls may be seen a very definite vegetational zonation. This varies on different atolls, but a certain order is usual, oriented concentrically from the outer beach to the inner, or lagoon, beach.

The outermost zone is a scrub, principally of *Scaevola frutescens*, reaching a height of 2-5 meters and often mixed on its inner edges with *Cordia subcordata* and *Soulamea amara*. On very narrow islets and spits between islets this may extend the full width of the islet. In sandy soil *Suriana maritima* may be an important component.

Next inward there is usually a halophytic forest zone of the tree heliotrope (*Messerschmidia argentea*) and *Pandanus*. In some regions, as in the Marshalls and Carolines, *Terminalia littoralis* is commonly found in this forest. This is ordinarily a rather narrow belt.

The greater part of the interior of an islet is usually occupied by a more mesophytic type of forest. At the present time on most atolls this is largely made up of coconut plantations, which, contrary to popular opinion, are not the natural vegetation of atolls but are planted by man. In places on the wetter atolls the coconuts are partly replaced by breadfruit trees which occasionally reach enormous size, towering above the coconuts and making a dense shade. *Pandanus* is also common among the coconuts.

Where scraps of the original vegetation of this zone remain they are found to be composed of such trees as *Pisonia grandis*, *Pandanus* spp., *Ochrosia parviflora*, *Pipturus argenteus*, *Hibiscus tiliaceus*, *Messerschmidia argentea*, *Calophyllum inophyllum*, *Barringtonia asiatica*, *Eugenia* sp., and others. On the drier islands the buka (*Pisonia grandis*) tends to be dominant.

In the interior of this zone there are frequently swales, marshes, ponds termed "man-



FIG. 3. Interior of Hare Islet, Kapingamarangi Atoll, Caroline Islands, showing undergrowth in coconut-breadfruit forest, with ground cover of *Stenotaphrum subulatum*. PHOTOGRAPH BY F. R. FOSBERG.

grove depressions" (see Fosberg in *N. Y. Bot. Gard., Jour.* 48(570): 128-138, 1947), or even fresh-water lakes, as on Washington Island. Here may be found sedges, grasses, and in the western Pacific, several plants of the mangrove formation. In the interior of this zone on the larger islands, the natives often excavate areas down to the water table, fill them with vegetable debris which decomposes to a muck, and therein plant taro (*Colocasia*), puraka (*Cyrtosperma*), and other cultivated plants which do not thrive on the normal atoll surface.



FIG. 4. Large excavated puraka patch surrounded by coconuts, showing sugar cane mixed with *Cyrtosperma chamissonis*, Nukuoro Islet, Nukuoro Atoll, Caroline Islands. PHOTOGRAPH BY F. R. FOSBERG.



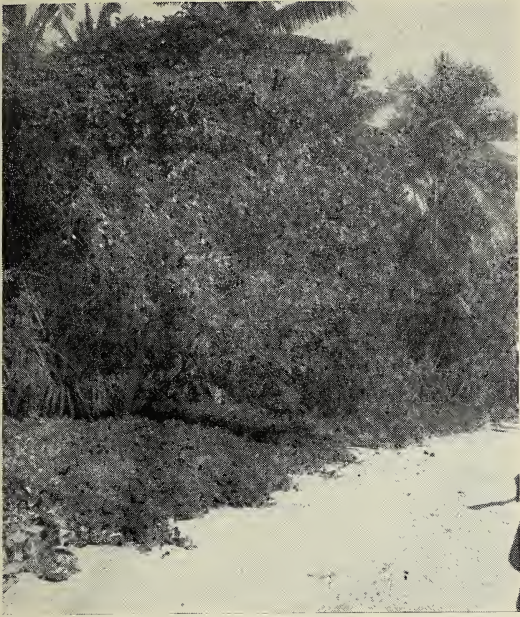


FIG. 5. Inner beach on Mejat'to Islet, Jaluit Atoll, Caroline Islands, showing *Cordia subcordata* tree and herbaceous vegetation. PHOTOGRAPH BY F. R. FOSBERG.

On the sandy inner shore, or lagoon beach, is a narrow strip of scattered trees such as *Cordia subcordata*, *Hernandia ovigera*, *Terminalia catappa*, *Barringtonia asiatica*, *Thespesia populnea*, and, in rocky places, *Pemphis acidula*. Here also are such sand-loving herbs as *Vigna marina*, *Triumfetta procumbens*, *Thuarea involuta*, etc.



FIG. 6. Village scene on Ebon Atoll, Marshall Islands, showing *Carica papaya*, *Crinum asiaticum*, and other cultivated species. Papaya showing chlorosis. PHOTOGRAPH BY LEONARD E. MASON.

In general the indigenous flora of atolls is more meager to the eastward in the Pacific, richer in the west, as would be expected from the isolation of those in the east and the proximity of the western ones to large islands with their complex floras.

The introduced flora, both wild and cultivated, is extremely limited. The wild introduced species are mainly shallow-rooted herbs. It was the cultivated flora that offered the original clue to the distribution of atoll vegetation. It was noticed that, though numerous species have been tried out, both by the plant-loving natives and by residents of foreign origin, relatively few of them have survived. Still fewer can be considered successful even under the protection and cultivation of man. Those that survive, but are not especially successful, show, without exception, signs of a severe localized chlorosis (yellow coloring) of the type usually associated with excessive sodium, with resultant deficiency of assimilated potassium and a more general chlorosis possibly associated with deficiencies of other ions due, perhaps, to high pH. *Lantana camara*, ordinarily a most aggressive weed, is yellow and sterile where planted in the Marshall Islands. Even some of the species, such as the papaya, which survive and reproduce themselves, are often chlorotic. Also these species are much more successful toward the center of an islet where the salinity is naturally lower. Very few of the introduced plants, excepting those which are themselves strand plants with a tolerance toward high salinity, or those which are shallow-rooted, thus living in the upper layers where the salt is to some extent leached out by rains, have succeeded in becoming naturalized.

That there is a high water table in this type of island is shown by the numerous wells only a few feet deep, dug by the natives. The water is ordinarily more or less brackish. Hence it is not reasonable to suppose that the sparseness of woody vegetation of the drier islands is due to actual physical lack of water, since the tree roots can undoubtedly go down to the water table. Physiological dryness resulting from high



salinity is doubtless the limiting factor. This would be mitigated in direct relation to the amount of rain that falls on the island and to the distance that salt water has to diffuse through the porous limestone and debris making up the island. Mesophytic conditions would exist in direct proportion to the predominance of outward flow of fresh water over the inward diffusion of salt. The pattern of the distribution of vegetation in relation to the general rainfall and to the land area of an islet is exactly what would be expected on this basis; the more mesophytic types of vegetation exist in the interiors of larger islands in relatively rainy regions. Native agriculture is a reflection of this also. Coconut and breadfruit culture is more or less coincidental with the inner, more mesophytic, forest, and the excavated taro patches are found in the interior, least brackish locations and are absent on the driest islands. On very dry islands there is no agriculture.

The distribution of herbaceous seed plants, general wherever there is sufficient sunlight, is a reflection of the leaching of the salt from the upper layers. Ferns are found only in the shade of the mesophytic forests.

The few mangroves found on atolls, again, reflect the same pattern. *Bruguiera conjugata* and *Lumnitzera coccinea*, which are found on high islands toward the inner edges of the mangrove swamps where the salinity is less, are on atolls in the brackish mangrove depressions, while the *Rhizophora* and *Sonneratia*,

which grow on the seaward sides of the swamps, are found on atolls on the highly saline shores of lagoons and in swamps with direct tidal channels.

Further support for this principle is found in the flora and vegetation of elevated atolls and reefs. Here, even with a small degree of elevation, the flora shows a marked increase in number of species and vegetation becomes more mesophytic. This is demonstrated in the slightly raised portion of Anaa Atoll, the more strongly raised Henderson Island, the high platform of Makatea Island, as well as in the jungle-covered limestone plateaus and cliffs of the Marianas and the southern Palaus. The salt would naturally be largely leached out in these situations.

*Summary:* The atoll flora, both native and introduced, is restricted to such species as can tolerate considerable salinity. The vegetation is controlled by the salinity of the ground water. The fresh water of an atoll islet exists in the form of a very shallow Ghyben-Herzberg lens, with its freshness directly proportional to the product of the rainfall and the distance from the beaches. The vegetation, as a result, is mesophytic in relation to the same factors, tending to be most luxuriant and arborescent toward the center of large islets in wet regions, and more sparse, desert-like, and predominantly herbaceous or dwarf-shrubby on beaches, spits, and small islets in climatically dry areas of the ocean.



# Further Notes on Cirripeds from the Ogasawara Islands

HUZIO UTINOMI<sup>1</sup>

IN AN EARLIER PAPER (Hiro, 1939) I described three interesting species of cirripeds (*Smiliium boninense* Hiro, *Pachylasma ecaudatum* Hiro, and *Balanus krügeri* Pilsbry) which had been collected by the late Dr. Hayato Ikeda in the Ogasawara (Bonin) Islands. The present paper, which deals with new material of his collection from the same locality, received recently through the courtesy of the Honorable Professor H. Ohshima and Dr. S. Miyake, of the University of Kyusyu, may be regarded as a supplement. The material consists of five species, one of which seems to be new to science.

I am greatly indebted to the gentlemen mentioned above for placing the late Dr. Ikeda's collections at my disposal.

*Calantica* (*Paracalantica*) *ikedai*  
subgen. et sp. nov.

Figs. 1, 2

Capitulum with 11 valves, much compressed, scalpelliform-triangular and covered with a smooth, yellowish cuticle; occludent margin nearly straight and parallel to long axis of capitulum, carinal margin oblique to the latter. The 11 valves with apical umbones except a pair of scuta, white, wholly calcified, closely fitting, with fine growth lines.

Scutum triangular, nearly as high as broad (*ca.* 6 mm. long and wide), with umbo slightly incurved at upper one-fifth of occludent margin; occludent and tergal margins nearly straight and basal margin evenly convex.

Tergum elongate, triangular, about three times as long as wide (*ca.* 12 mm. long and 3.5 mm. wide), oblique to long axis of capitulum,

with nearly straight margins, end not reaching base of capitulum. (Its apex is partially damaged but probably bears the umbo at its pointed end, from which a slight ridge runs to the base.) Occupying the whole space between scutum and carina.

Carina extremely long (*ca.* 16 mm. long and 2 mm. wide), nearly straight and sharply pointed at end projecting beyond apex of tergum. Dorsal roof strongly arched along medial line, sides rather narrow. Basal end reaching upper level of subcarina.

Rostrum prominently large, pyramidal, about twice as high as broad (*ca.* 6.5 mm. long and 3.2 mm. wide), and projecting outwards; upper or inner surface slightly hollowed out with a medial, narrow, deep groove and bordered on each side by a low lateral rib. Basal margin strongly concave.

Rostral latus obliquely triangular, very large, about two and one-half times as wide as high, with blunt apex toward rostrum. Basal margin occupying more than half of the basal breadth of capitulum.

Upper latus and inframedian latus absent.

Carinal latus smallest of all valves, obliquely triangular, with apical umbo which curves toward scutum and overlies its baso-lateral margin. Strong broad rib along scutal margin from apex to basal angle, which is overlaid by the rostral latus. Valve thus occupying narrow space between scutum and subcarina below tergum.

Subcarina much stronger than rostrum, horn-like, strongly projecting beyond carinal margin, with incurved apex, from which two small ribs extend along inner margin on each side. Length *ca.* 8 mm. and breadth *ca.* 3 mm. Baso-scutal angle attached closely to baso-carinal angle of

<sup>1</sup>The author's name was formerly Fujio Hiro. Seto Marine Biological Laboratory, University of Kyoto, Sirahama, Wakayama Pref., Japan. Manuscript received July 13, 1948.

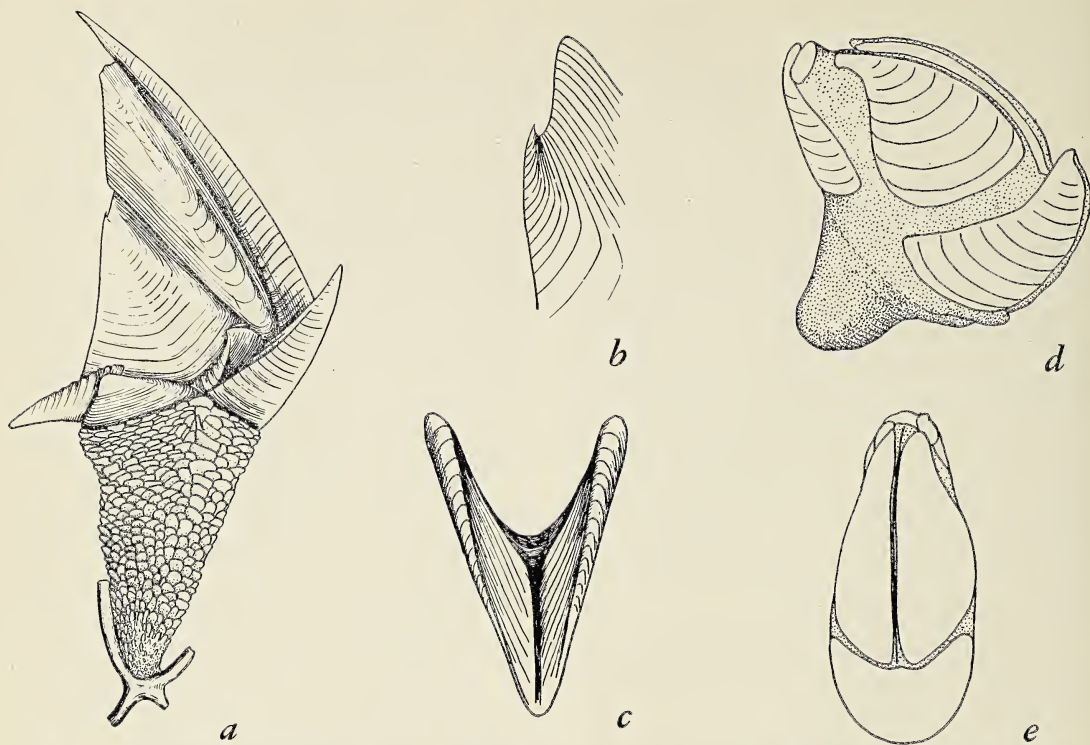


FIG. 1. *Calantica* (*Paracalantica*) *ikedai* subgen. et sp. nov.: *a*, specimen in lateral view,  $\times 3$ ; *b*, umbonal portion of scutum,  $\times 6$ ; *c*, rostrum in upper view,  $\times 6$ ; *d*, complementary male in lateral view,  $\times 30$ ; *e*, the same in upper view,  $\times 30$ .

rostral latus just below carinal latus; thus basal margin occupies less than one-half of basal breadth of capitulum.

Peduncle a little shorter than capitulum, tapering downwards and densely covered with somewhat large, strongly imbricating, white, calcified scales. Scales invested by yellowish cuticle except for disintegrated apices, rather broad, becoming club-shaped toward base of peduncle; row extending downwards longitudinally from point of junction between rostral latus and subcarina noticeably larger than elsewhere.

*Mouth parts:* Labrum concave, without teeth. Palpus elongate, with long bristles along somewhat rounded extremity.

Mandible with four teeth, second smallest, and rounded lower angle slightly pectinated.

Maxilla I with spines of three different sizes; two spines on upper angle are largest, those on middle somewhat shorter and slender, shortest ones on the strongly protruded lower angle.

Maxilla II roughly quadrangular, with bristles on entire edge.

Cirri ordinary in segmentation and armature; both rami of each cirrus subequal in length, segments a little longer than wide and bearing five pairs of ventral bristles and one long and two short dorsal bristles at the distal angle. Protopodites robust. The numbers of segments of the cirri are as follows:

I	II	III	IV	V	VI
13 15	14 16	17 16	21 20	20 20	20 21

Caudal appendage uni-articulate, a little longer than one-half the length of lower segment of protopodite of cirrus VI, terminating in a brush of a few short bristles.

Penis extremely short, about as long as protopodite of cirrus VI, very feebly annulated, provided with fine hairs distally.

One complementary male is present in the usual position in front of the adductor scutorum muscle. Although it has the typical appearance of the male of the genera *Calantica* and *Smilium*,



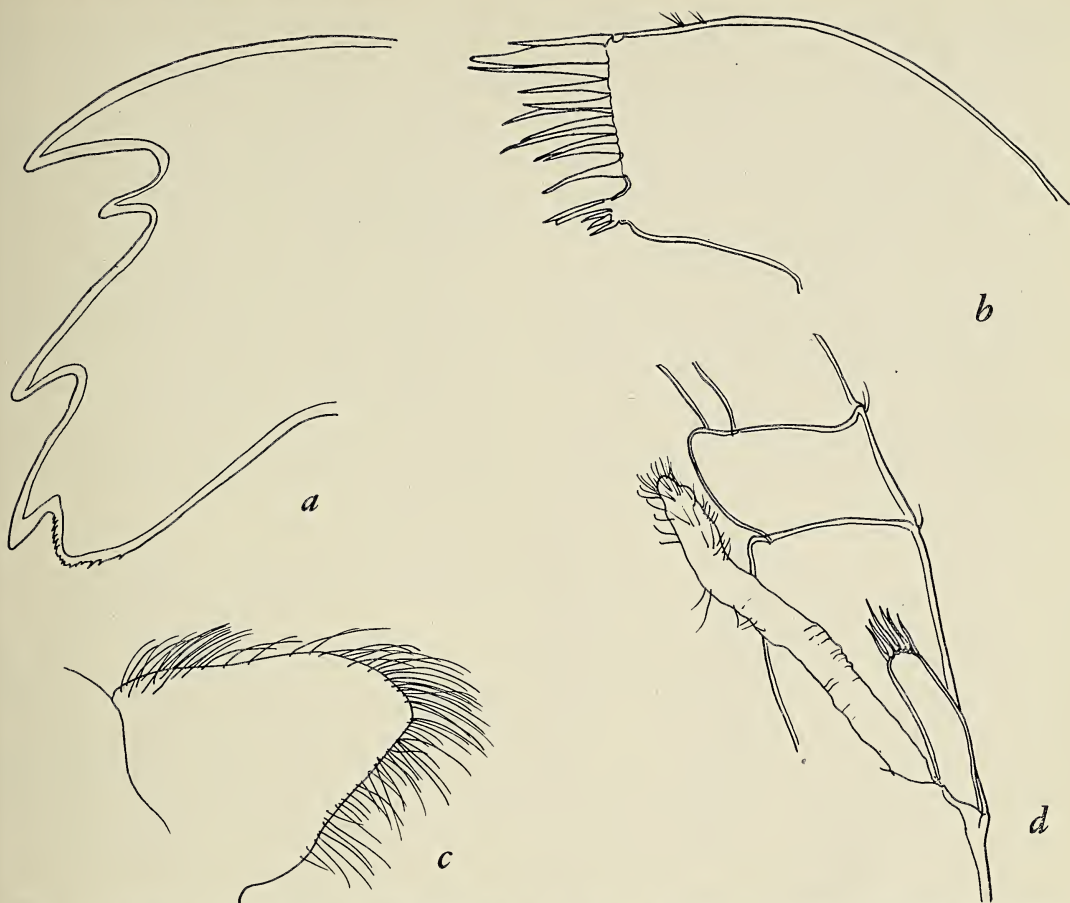


FIG. 2. *Calantica* (*Paracalantica*) *ikedai* subgen. et sp. nov.: a, mandible,  $\times 125$ ; b, maxilla I,  $\times 125$ ; c, maxilla II,  $\times 55$ ; d, lower part of cirrus VI, with penis and caudal appendage,  $\times 30$ .

consisting of a large capitulum with six valves and a short peduncle, it differs somewhat. Of the valves, two scuta, one rostrum, and one carina are extremely large and triangular, while two terga are rather rudimentary and oval in outline. The carina is not visible from outside, *in situ*, being situated basally below the scuta. The peduncle is wholly buried in the cuticle of the hermaphrodite. It is about 1 mm. long and 1.3 mm. wide.

*Measurements in mm.:*

Length of capitulum.....	17
Length of peduncle.....	11
Basal breadth of capitulum.....	8

*Locality:* Ogasawara Islands. Depth unknown. One specimen on a gorgonian stem. Aug. 1, 1938, Ikeda *leg.*

*Remarks:* The general outline of this cirriped is more like that of the genus *Smilium* than that of *Calantica*, the capitulum being not *Mitella*-like but *Scalpellum*-like in form. However, the upper latus is entirely lacking, a condition not dependent entirely on accidental reduction because of its special environmental location. The upper whorl of valves consists of the paired scuta and terga, and a closely fitting carina, the tergum occupying the whole of the space between the scutum and carina, as in *Calantica*; the lower whorl consists of only two pairs of latera, a rostrum and a subcarina, all being well developed. The scutum is triangular in form as in *Calantica*, but has the subcentral umbo. The subcarina is extraordinarily larger than the rostrum, instead of being somewhat smaller as in *Calantica*. The peduncular scales are wholly

calcified, and compactly imbricate as in *Mitella* and also *Scillaelepas*. The complementary male bears the rudimentary terga, though the general features are somewhat similar to those of *Calantica* as well as of *Smilium*. These peculiarities seem to me to justify the institution of a new subgenus, *Paracalantica*, under the genus *Calantica* Gray, for this cirriped. As I have only a single specimen at present I do not venture to separate it generically from the latter genus. The subgenus *Paracalantica* is diagnosed as follows:

Scalpellidae with a capitulum of 11 valves forming two whorls; upper whorl comprising paired scuta, terga, and a carina, the tergum occupying the space between scutum and carina; lower whorl comprising two pairs of latera, a rostrum, and a subcarina. Subcarina and rostrum very large, high, the former stronger than the latter. Scutum with umbo subcentral; umbo apical in remaining valves. Peduncle with imbricate scales. Male with a capitulum, comprising four large valves and rudimentary paired terga, and a short peduncle.

In the reduction in the number of valves as well as in the peculiar habitat, this cirriped seems to be somewhat allied to *Smilium hypocrites* Barnard (1924). The specimen is completely overgrown by the coenenchym of the gorgonian and by the polyps, which contain abundant spicules, as well. However, this cirriped in no way indicates such reduction in the size of all valves as is shown in *S. hypocrites*, which, according to Barnard, is "a true *Smilium* in process of simplification owing to its protected habitat." It is thus doubtful whether his species is to be placed in the same group as the present species.

#### *Trilasmis (Trilasmis) eburnea* Hinds

This curious cirriped has occasionally been found attached to spines of echinoids from the Malay and Hawaiian Archipelagoes. The specimen examined here measures about 4 mm. in length of capitulum, 2.5 mm. in breadth of capitulum, and 1.3 mm. in length of peduncle.

This is the second record of its occurrence in our territory, since I have recorded it once from off Tonda near Seto (Hiro, 1937).

*Locality:* N. 27°16', E. 140°55', southwest of Titi-zima, 500 fathoms. One specimen on a spine of the sea urchin *Pseudoboletia* sp., Aug. 1, 1938, Ikeda leg.

#### *Balanus (Chirona) krügeri* Pilsbry

This species was recorded from the Ogasawara Islands (Hiro, 1939). The present material consists of two specimens attached to spines of a sea urchin, together with the following two barnacles. One of them measures about 10 mm. in carinorostral diameter and 7 mm. in height.

#### *Balanus (Solidobalanus) hawaiiensis*

Pilsbry

Fig. 3

This species was first described by Pilsbry (1916) on specimens attached to spines of the sea urchin *Phyllacanthus thomasi* Agassiz, taken from the Hawaiian Islands at a depth of 21–222 fathoms. Since then there has been no record of its occurrence whatever. The present specimens agree well with the description and figure of Pilsbry. This cirriped, together with *Balanus pseudauricoma*, found on the sea urchins is adequately shown in the photographs appended to Ikeda's paper on the host sea urchin (1939: pl. 7, 8).

The specimens are very small, conical, white, and tinged with some pink or light reddish-purple transverse stripes. The wall is provided with prominent ribs on each compartment, the carina and latera having two strong ribs, the carinolatera a single one, and the rostrum two. The interval between the ribs is broadest and deepest in the lateral compartments. The radii are wide, transversely striped, and their oblique summits are usually ribbed because of the up-turned, prominent growth lines. The alae have straight, smooth, and nearly level summits. The orifice is wide and quadrangular.

The opercular valves differ somewhat from



the original description, but the difference is probably unimportant. The tergum seems to be more narrowly elongate than in the Hawaiian specimens, and nearly akin to that of *Balanus auricomus* Hoek, but there is no doubt that they are specifically distinct in other respects.

The mouth parts agree in all particulars with the description of Pilsbry. The same is also established as regards the cirri.

*Measurements in mm.:*

	Specimens			
	A	B	C	D
Carinorostral diameter.....	6.0	5.8	5.3	4.9
Height .....	3.4	3.8	2.5	2.6
<i>Locality:</i> N. 26°40', E. 140°55', southwest of				

Titi-zima, 70–80 fathoms. Twenty-four specimens on spines of the sea urchin *Compsocidaris pyrsacantha* Ikeda, together with *B. pseudauricomus* and *B. krügeri*.

***Balanus (Solidobalanus) pseudauricomus*  
Broch**

**Fig. 4**

This species has heretofore been recorded by Broch (1931) from the Menado Bay, Celebes, and west of Nagasaki (N. 32°25', E. 128°33') at a depth of 400 to 500 m. The present specimens may be referred to this species, though some slight differences are found to occur.

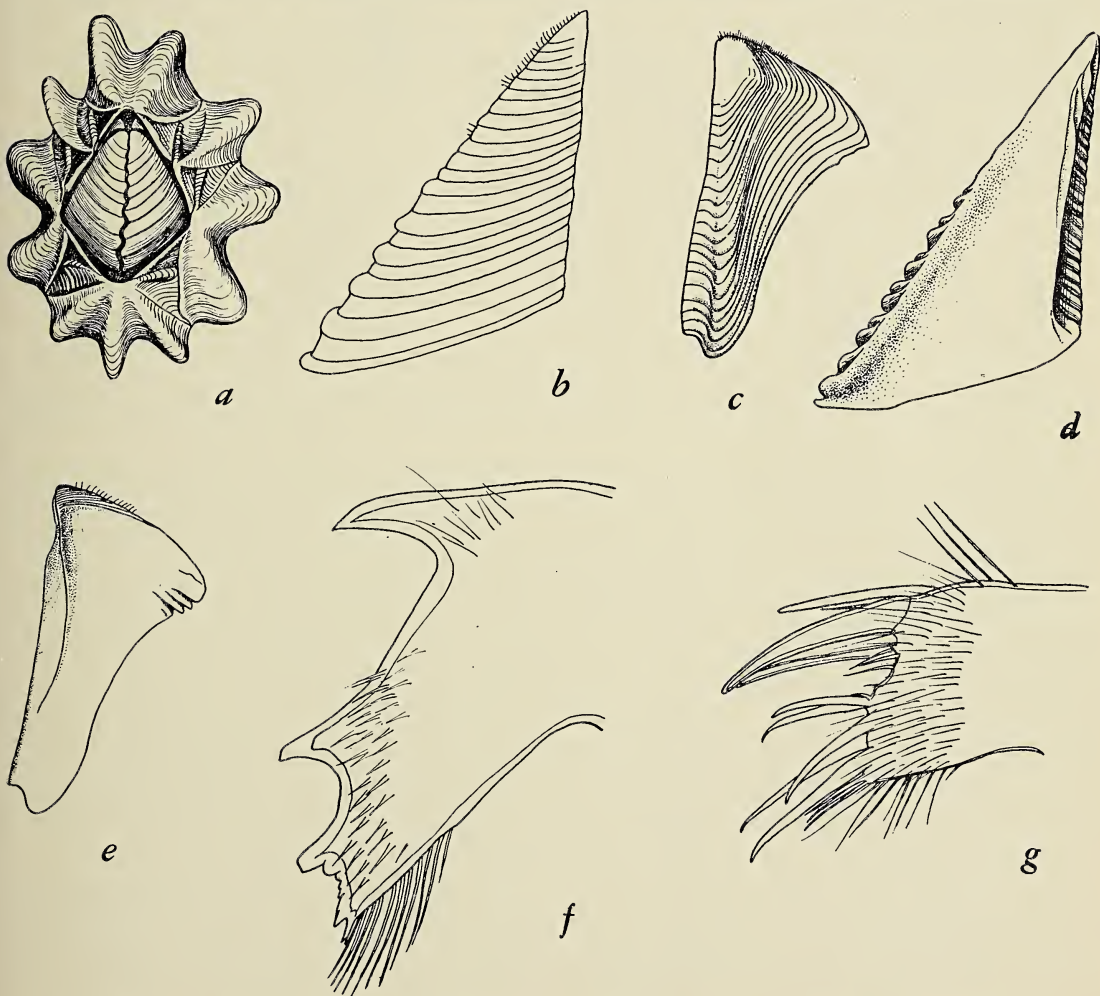


FIG. 3. *Balanus hawaiiensis* Pilsbry: *a*, specimen in upper view,  $\times 8$ ; *b*, outer side of scutum,  $\times 24$ ; *c*, outer side of tergum,  $\times 24$ ; *d*, inner side of scutum,  $\times 24$ ; *e*, inner side of tergum,  $\times 24$ ; *f*, mandible,  $\times 187$ ; *g*, maxilla I,  $\times 187$ .

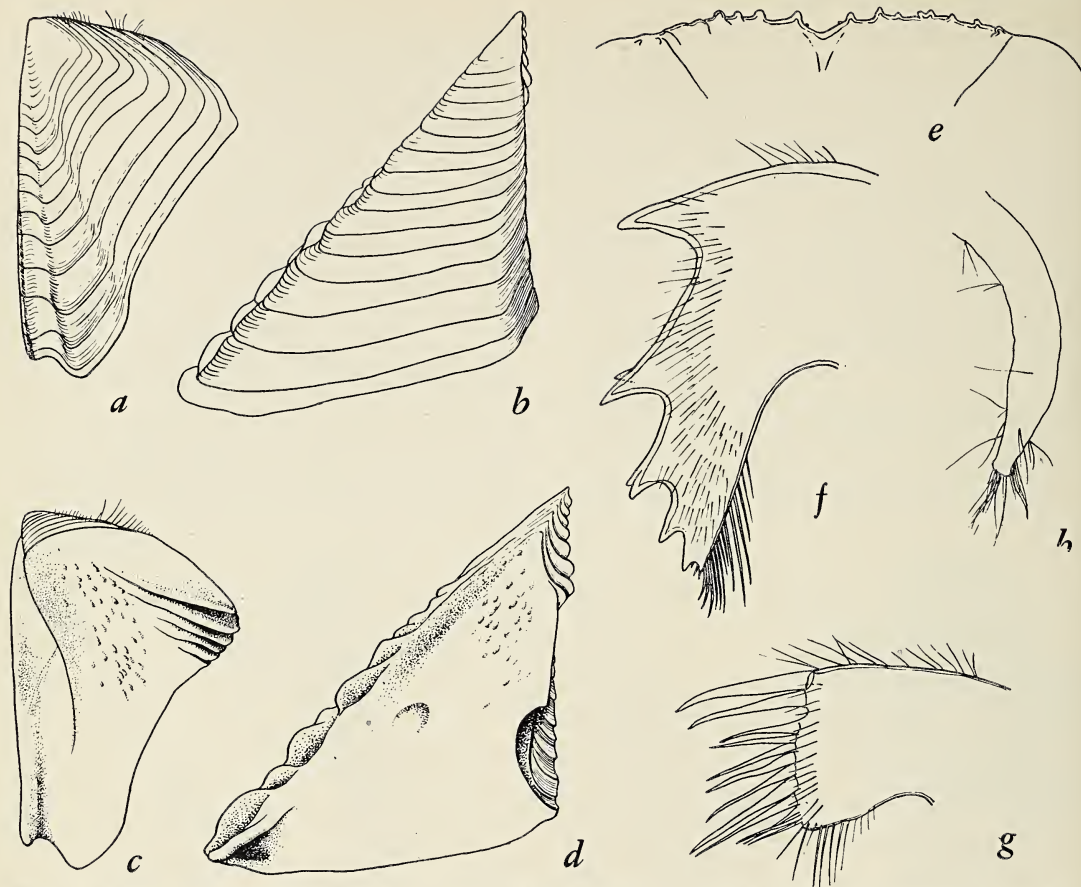


FIG. 4. *Balanus pseudauricomus* Broch: *a*, outer side of tergum,  $\times 15$ ; *b*, outer side of scutum,  $\times 15$ ; *c*, inner side of tergum,  $\times 15$ ; *d*, inner side of scutum,  $\times 15$ ; *e*, labrum,  $\times 62$ ; *f*, mandible,  $\times 50$ ; *g*, maxilla I,  $\times 50$ ; *h*, distal part of penis,  $\times 50$ .

The compartments are smooth, wholly glossy white, without any colored stripes, but in younger specimens tinted with pink color all over. They are thick, solid, and finely ribbed longitudinally on the inner face. The base is radially ribbed, but not porous.

The scutum has plain growth lines, widely separate, and exhibits no longitudinal striation; Broch found delicate, though distinct, longitudinal striation in the median part of the scutum on his specimens. This character is, in my opinion, of little value, as it is often found in other cirripeds. The articular ridge is absent. There is a faint indication of a pit for the adductor muscle, as a small rounded depression, though it is sometimes lacking. There is, however, no distinct pit for the lateral depressor muscle, although Broch recognizes its presence.

The tergum exhibits a shape similar to that of Broch's specimen. It has a shallow and wide furrow running from the apex to the end of the spur; according to Broch, however, "no spur fasciole or furrow but a narrow and distinct furrow runs parallel with the scutal margin limiting the spur area."

In both of the valves, the upper part of the inner face is usually roughened with many tubercles. The occludent margin of the scutum and the carinal margin of the tergum are sometimes colored pale orange.

The mouth parts exhibit all the peculiarities of *B. pseudauricomus*, especially the labrum, which has a very shallow notch and on each side of it seven or eight obtuse teeth (according to Broch, four or five) arranged irregularly. The mandible has five teeth of which the second



and third are bifid, and the fifth is rudimentary. Maxilla I has a distinct but narrow notch.

The cirri have the following numbers of segments in their rami:

I	II	III	IV	V	VI
7 12	12 12	11 11	23 25	27 30	30 30

On the whole the numbers of segments are much larger than those of Broch's specimen, but the other characters agree with his description.

Although some differences, mentioned above, are found between the present specimens and Broch's *pseudauricoma*, these seem to be so small and of such subordinate importance as to be insufficient for a specific separation.

Measurements in mm.:	Specimens			
	A	B	C	D
Carinorostral diameter.....	6.7	6.1	5.9	5.4
Height .....	4.0	4.0	4.8	3.2

Locality: The same as given for *B. hawaiiensis*. Ten specimens.

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## NOTES

### Range Extension of the File Fish *Monocanthus melanocephalus*

On June 9, 1948, a "kawakawa" (*Euthynnus yaito* Kishinouye) was caught from surface waters three miles south of Makapuu Point, Oahu, Hawaii. The stomach of this fish was removed and the content preserved in 7 per cent formalin solution. Eleven identical fish of the family Monacanthidae were included in the stomach content. The least damaged specimen was identified as a young *Monocanthus melano-*

*cephalus* Bleeker.

Available literature indicates that this species of fish is known from East Indian waters and through the tropical Pacific as far east and north as Johnson Island. This is the first record of its occurrence in Hawaiian waters.—James P. Welsh, Division of Fish and Game, Territorial Board of Agriculture and Forestry, Honolulu, Hawaii.

## News Notes

Beginning with the current year new members of the Board of Editors of *Pacific Science* will serve for a term of three years. It is felt that such a system will insure both a desirable continuity and a healthful change of personnel. With this issue we welcome the following new members to the Board: Robert W. Hiatt, G. L. Kesteven, Luna B. Leopold, J. P. Martin, and John J. Naughton.

*In Gardens of Hawaii.*—A book "intended for use by amateurs as a floral guide to Hawaii, chiefly plants found at warm low altitudes," is the characterization given by the author. Botanists and other biologists will also find it useful, however. A total of 2,020 species of plants is covered, 600 of them illustrated. Those included are primarily ornamental and food plants, introduced from all parts of the world. Ferns and their allies, gymnosperms, and angiosperms are treated. Keys to genera are included. Additional features are the calendar for the flowering time of some of the best known ornamentals and color keys to the flowers and fruits of many of the species. Native Hawaiian names and legends are included where these are known.

NEAL, MARIE C. *In Gardens of Hawaii*. 805 p., 312 figs. Bernice P. Bishop Museum, Honolulu, 1948. Price \$8.00.

*Conservation in Micronesia.*—(A report on two conferences held under the auspices of the Pacific Science Board in Honolulu, T. H., and Washington, D. C., in April and May 1948.) Compiled by Harold J. Coolidge, Executive Secretary, Pacific Science Board. 70 p. National Research Council, Washington 25, D. C. Price \$1.00.

This important compilation presents some of the plans for conservation of the flora and fauna, as well as of the human inhabitants and their cultures, in the Trust Territories of the Pacific, together with both general and specific recommendations for achieving this conservation made by participants in the two conferences.

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, have been received. Each report includes a list of all those published, their distribution, and rules for obtaining them.

*Canned Crab Industry of Japan*. Report No. 109. 52 p., 17 figs.

*Reconnaissance Soil Survey of Japan. Kanto Plain Area*. Report No. 110-A. 72 p., 1 fig., 1 pl., 9 maps.

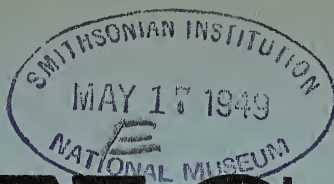
*English-Japanese Terms. Mining and Petroleum Industry*. Report No. 111. 52 p.

*Lignite in Japan*. Report No. 112. 52 p., 22 figs., 1 map.

*Mining Practices at Matsuo Pyrite Mine Japan*. Report No. 114. 40 p., 2 figs.

*Asbestos Resources of Japan*. Report No. 115. 36 p., 4 figs., 1 pl.





# PACIFIC SCIENCE

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## Populations of Birds on Midway and the Man-Made Factors Affecting Them

HARVEY I. FISHER<sup>1</sup>

THE BIRDS of Midway are of interest and importance for several reasons. They are of interest to professional ornithologists because of their great numbers, their ecology, and because some of them breed in no other region of the world except that of the leeward islands of Hawaii. The endemic species are of great interest *per se*. To the chance visitor to the atoll and to the men stationed there in military service the birds constitute a beneficial recreational and morale factor. Certain of the species would be of significance to a fishing industry if it were ever established in this area, since by their concentrations over schools of forage organisms they indicate to the fisherman the location of schools of marketable fish feeding on the same organisms.

Chapman (1946: 166) has emphasized recently the importance of birds to any fishing done in the area around Midway. He states,

Fishing was done entirely, after some experience, by following the flocks of seabirds which were feeding on the same organisms as the fish. The birds were actively scouting for food all during the sunlit hours. They gathered over the spot where the fish would rise, some seconds or minutes before the fish came to the surface, in sufficient numbers that the flock could be seen for three or four miles, and they would follow a feeding school as long as it stayed at the surface. They furthermore seemed able to estimate where a school of fish would rise next with far better precision than we could, and when there were no fish in sight we formed the habit of idling the boat near a large flock of resting birds with the assurance that if they were not in the right place their scouts, which were always out, would lead them quickly to the right place before the fish rose to the surface. Fairy terns,

because they were pure white and could be seen so far away, were particularly valuable in sighting distant schools as were the high flying frigate birds, but it was the mutton birds and boobies that formed the main mass of feeding birds.

With postwar expansion in Hawaiian fisheries already including French Frigate Shoal, it seems probable that the colonies of birds on islands farther to the west, Laysan, Pearl and Hermes Reef, Midway, and Kure, will become important to commercial fishermen.

In view of these facts it seems worthwhile to assemble all information relative to the trend of populations of the species inhabiting Midway Atoll and to investigate the man-made factors, past and present, that cause shifts in population numbers. This is the primary purpose of this paper. As an auxiliary objective, I wish to note the recovery of the populations since May, 1945, when a definite program of conservation was first initiated. Most of this latter information is based upon a survey which I made in late December of 1946.

I wish to express my sincere appreciation for the aid and hospitality of Captain R. W. D. Woods, Commanding Officer of Midway, during my visit in December, 1946. He arranged transportation to Midway and gave all possible assistance. I also wish to thank Commodore Gale Morgan and Commodore Gordon Rowe, successively in command at Midway prior to Captain Woods, for their genuine interest in the avifauna and their initiation of protective measures. Dr. Alexander Wetmore of the United States National Museum and Mr. Chapman Grant, who were members of the "Tanager"

<sup>1</sup>Department of Zoology, University of Hawaii. Manuscript received February 14, 1948.

Expedition in 1922, graciously permitted me to use their unpublished estimates of the bird populations on Midway.

Since 1900 the populations of birds on Midway have been subjected to several periods of serious disturbance. Shortly after the turn of the century the atoll was twice visited by commercial plume hunters; it is likely that the island was ravaged by these hunters at least once more between 1910 and 1920. From 1920 to the late 1930's the breeding birds were not disturbed to any great extent. With the appearance of war in Europe and the threat of war in the Pacific, the islands of Midway became the site of great activity, which included vast construction projects, the stationing of thousands of men on the small islands, and, finally, the inadvertent introduction of the rat.

To discuss these major man-made disturbances or catastrophes in chronological order, the effects of the plume hunters must be considered first. We do not know how great the total numbers of each species were at the time of the slaughter or what proportion of the total population was killed. Accounts such as those of Bryan (1906, 1910), Dutcher (1905, 1907), and Henshaw (1911) indicate that hundreds of thousands of birds were killed in these forays on Midway, Laysan, Marcus, and Lisianski islands. On Laysan more than 300,000 birds were killed between May, 1909, and the fall of the same year. Over half a million were slaughtered on Lisianski. Exact figures are not known for the number killed on Midway, but several descriptions would lead one to believe that perhaps another half million birds were taken. On Marcus Island the feather hunters in 6 years practically eliminated a colony of albatrosses numbering at least one million birds. Although the Laysan and Black-footed Albatrosses were the species most desired, additional species known to have been taken in considerable numbers on Midway were: Frigate, Red-tailed Tropic Bird, Bonin Island Petrel, Christmas Island Shearwater, Wedge-tailed Shearwater, Red-footed Booby, Blue-faced Booby, Fairy Tern,

Sooty Tern, Gray-backed Tern, Noddy and Hawaiian Tern, and a number of migratory species including the Golden Plover, Bristle-thighed Curlew, and the Ruddy Turnstone. On Laysan three other species were collected—the Laysan Teal, Rail, and Finch.

The effect on the populations of birds cannot be reckoned solely on the basis of the number of adults killed for their plumage. Continued depredations during any one season probably resulted in the loss of both parents of many young birds. This in turn led to the death of the young and in many instances practically eliminated the annual increment. Where the hunting lasted one year only those birds which had been at sea and had not been breeding at the time of the hunting were left to perpetuate the species. In some seabirds the number of non-breeding birds in any one season seems to be quite sufficient to form a nucleus for a colony the next year. On islands such as Marcus, where the plume hunters were undisturbed for several years, many species almost disappeared, for each year the breeding birds were killed and the increment was lost. Resident species, where present, suffered the most from continuous hunting.

Aside from natural epidemics, such as that reported by Bartsch (1922) as affecting the Sooty Terns, there was little disturbance of the nesting grounds between 1910 and the late 1930's, when the war-caused activities started. The effects of the war can best be discussed in three groups: (1) effects of construction for war; (2) effects of daily use of the breeding grounds during the war; (3) the after-effects of the war, such as the continuing adverse pressure by rats on the bird populations.

The main period of construction for war lasted more than 18 months on Midway. Thus it covered at least once the breeding season of every species on the island. Moreover, with the exception of the area around the Cable Compound, which had tall ironwood (*Casuarina*) trees, and a few small isolated areas of *Scaevola*, almost the entire surface of the two main islands



was either smoothed for roads, filled for underground installations, paved for airplane runways, or covered by stored material or buildings. Consequently, ground- and burrow-nesting species were especially hard-hit; these included the albatrosses, the shearwaters and petrels, the Noddy Tern, the Blue-faced Booby, the Red-tailed Tropic Bird, and the Laysan Rail. Also affected were the species nesting on *Scaevola* branches — Hawaiian Tern, Frigate, Laysan Finch, Red-footed Booby, and Fairy Tern.

The nesting sites were usurped and made undesirable, permanently in some instances, by the presence of these installations. The process of construction also proved detrimental. It could be expected that most of the shearwaters and petrels (and their eggs and young) would be destroyed in their burrows by the activities of bulldozers filling and smoothing nesting areas. Because construction activities went on 24 hours a day, diurnal as well as nocturnal birds were affected. Eggs and young of Sooty and Noddy Terns, Blue-faced Boobies, Tropic Birds, and Laysan Rails undoubtedly met the same fate; the adults could and probably did move out of harm's way. However, the adults of some species would not leave their eggs or young and therefore they were destroyed in one way or another. The following account (Woodbury, 1946: 149–150) indicates how the albatrosses fared during the construction period.

The men soon tired of watching the birds but they couldn't get rid of them. Everywhere a man drove a cat or a bulldozer, the vast populations of birds stood in the way, bowing and whacking beaks or simply staring off to sea. Small gray babies nestled in little hollows made for them by their elders and refused to move out. They didn't dare, for they got roundly scolded whenever they left the nest. Washington had sent word that the goonies must not be hurt, so for a while Gallagher had to detail an extra man to walk in front of every vehicle, awkwardly requesting the birds to step aside, setting the young out of harm's way one at a time.

Gallagher protested that too much time was being lost; with Ventres' permission, he gave orders to run over the creatures. This didn't

work any better, for the dead birds raised such a terrible smell that they had to be picked up one by one and disposed of.

Midway never did find a satisfactory solution to its bird problem. A year later, when the land-plane runways were in, the goonies became such a serious menace to the fliers that the Navy ordered their extermination. Marines and construction men armed with two-by-fours and rods of reinforcing steel clubbed thousands to death — with almost no effect upon the population[?].

Although the work of construction never ceased entirely, the most detrimental period was just before and during the early years of the war. Despite the cessation of major construction activities the birds continued to be affected adversely by the various structures erected and by the continuous over-all use of the entire island. Fisher and Baldwin (1946: 10–13) have discussed this phase of the war's effect on the birds, but additional data and a re-evaluation of these factors seem to make a review desirable. Fences, barbed-wire entanglements on the beaches, towers, overhead wires, and poles proved to be definite hazards to albatrosses and other species. Pits, foxholes, and gun emplacements trapped albatrosses, tropic birds, shearwaters, and petrels, resulting in their death by starvation. More important than the structures that caused physical injury to individual birds was the presence of so many structures (buildings, roads, paved runways) on so much of the surface of the nesting areas. Nesting sites of all ground- and shrub-nesting species were thus usurped and the breeding potential of the birds reduced.

All movable vehicles, from bombers to jeeps, killed thousands of all avian species inhabiting the islands. Airplanes were especially detrimental to the great wheeling flocks of Sooty Terns and Red-tailed Tropic Birds. Albatrosses of both species were killed in the air, as the following account from Woodbury (1946: 374) shows: "The goonies, likewise, cared nothing for the military safety of the station. Any pilot who took off or landed on the gleaming new runways could be sure of hitting half

a dozen of them, sometimes bending a prop or cracking a windshield. Worst of all, the goonies loved to fly in groups, sitting almost motionless high in the air in a perfect battle formation that fooled many a lookout and sent the island to battle quarters more than once." At night the shearwaters and petrels were killed in the air. However, it was not only in the air that planes killed birds; in landings, in take-offs, and in moving from place to place on the ground the planes were forced to pass through flocks of birds on the runways and parkways. Sooty and Noddy Terns, Wedge-tailed Shearwaters, both albatrosses, and Bonin Island Petrels were prone to alight on the runways which no doubt covered parts of their former nesting grounds. Trucks, jeeps, and other passenger vehicles which were constantly moving about on the narrow, *Scaevola*-bordered roads ran down countless thousands of individuals of these species. Further, vehicles sometimes left the roads and traveled "cross country" through colonies of ground-nesting terns, killing young and adults and smashing eggs; or they went across areas honeycombed by the burrows of shearwaters and petrels with the same result.

The presence of so many human beings (about 15,000 at one time) on so small an area (less than 2 square miles) was also an important factor in reducing the populations. In December, 1946, less than 1,000 people were stationed at Midway, but in the future the permanent complement of military personnel may be about 3,000. Psychological disturbances to all species no doubt reduced the success of their nesting; most adversely affected were the colonies of Sooty Terns, Gray-backed Terns, and Fairy Terns. Albatrosses, Red-tailed Tropic Birds, and Red-footed Boobies seem less disturbed by the mere presence of man near the nest, but the actual effect on them is unknown. The nocturnal, burrow-nesting species were least affected, as far as psychological disturbances were concerned, but these species were the most hated by the men and consequently suffered more physical violence. The adults were killed,

their young and eggs destroyed, and their burrows tramped shut. It should be noted that this persecution of shearwaters and petrels was limited for the most part to the Wedge-tailed Shearwater and the Bonin Island Petrel; Bulwer's Petrel and the Christmas Island Shearwater suffered less because of their relative scarcity and because they are limited to Eastern Island which always had fewer men stationed on it than did Sand Island. The Wedge-tailed Shearwater was also subjected to another form of human depredation—the daily gathering of eggs for food. The extent of this form of adverse pressure is unknown for Midway, but it did occur.

Wanton killing of birds (other than the "moaning birds") by military personnel during the war was probably a relatively unimportant factor in decreasing the populations, and naval authorities set up stringent, but sometimes bypassed, regulations about it.

No doubt the most serious factor brought by man was the rat, which was inadvertently introduced early in 1943. By the time control measures were initiated in 1945, it was computed on the basis of bait eaten from feeding station pans that the rat population was greater than 100 per acre. Trapping and poison baits aided in controlling the rats during 1945 and the first half of 1946 at which time the scope of the control program had to be reduced because of lack of personnel. However, the control never was complete, and since 1944 rats have exerted a depressing effect on various species. The Bonin Island Petrel, Bulwer's Petrel, and the Fairy Tern have suffered from rats. Extinction of the Laysan Finch and Laysan Rail may be attributed principally to rat depredations. The Hawaiian Tern, although it is a shrub- and tree-nesting species, has been affected. Alsatt (1945: 49–51) noted that adults of the Fairy Tern were not obviously fewer in numbers, but fewer young were seen in early 1945. Further, he found that immature birds under observation disappeared overnight. The decline in numbers of the Domestic Canary also started with the introduction of the rat.



The rat problem is a continuing one and forms an important part of the third category, the after-effects of the war on the birds. As long as men were available and as long as the military authorities had sufficient reason (other than birds) to keep the control program functioning, the rat populations were held in check. With the close of the war and the virtual abandonment (withdrawal of all personnel) of Eastern Island of Midway, the rats began to increase. In December, 1946, rats were quite in evidence on both Sand and Eastern Islands, but especially on the latter. Since the populations of Christmas Island Shearwaters and of Bulwer's Petrels are small, and since at Midway they occur only on Eastern Island, they are in real danger of elimination. It seems probable that on Sand Island some sort of control program will always be in effect, but it is doubtful whether the numbers of rats will be reduced sufficiently to stop their depredations on birds.

Other lasting effects of the war include the effects of acres of pavement put down for runways over the central parts of both islands. This pavement, as indicated earlier, covers the most heavily used breeding grounds of the Laysan Albatross, Wedge-tailed Shearwater, Bonin Island Petrel, Red-tailed Tropic Bird, and Sooty Tern. The area is lost for breeding activities. Macadam roads produce the same effect. It is true that Noddy Terns, albatrosses, shearwaters, and petrels have already moved back to the shoulders of the runways. Little-used coral roads through the *Scaevola* are being reclaimed as nesting areas by both species of albatrosses, but these nesting birds are liable to destruction by any passing vehicle. Many gun pits, foxholes, and other traps have been filled in, but some will no doubt remain for years. Buildings still cover many former nesting sites. However, for the most part the buildings are temporary and will simply disintegrate if they are not removed. Both species of albatrosses are now nesting in and around such buildings.

In addition to factors which have worked to the detriment of the birds there have been a

few, man-made, beneficial factors. Before the establishment of the Cable Station there was not much vegetation on Sand Island, and Eastern Island was called Green Island. The reverse is true now, due chiefly to the early (about 1906) activities of the employees of the Commercial Cable Company in planting ironwood trees, a coarse grass (*Ammophila arenaria*), and many other exotic plants on Sand Island. A nursery was established to provide further plantings. Pan American Airways aided in the work of planting Sand Island. The United States Navy planted sand-stabilizing grasses, as well as ironwood trees, sea grape (*Coccoloba*), and tree heliotrope (*Messerschmidia*). Most of these plantings are taking hold well and in time those of the last 6 years will replace much of the cover that was destroyed early in the war.

The effect of a greater amount of plant growth on birds is variable from species to species. There is little doubt that the presence of ironwood trees which provide many safe nesting places has increased the populations of Fairy and Hawaiian Terns. Bryan (1906), who visited Sand Island in July and August, 1902, found only 12 to 20 Hawaiian Terns, and long-time employees of the cable company say that Fairy Terns are much more numerous than they were 20 years ago. During the height of the depredations by rats the Domestic Canaries took refuge in the ironwood trees for safer nesting. These trees are also used by the Domestic Pigeons, which are becoming numerous. The last holdout of the Laysan Finch was in the ironwood trees and hibiscus hedges planted by the employees of the cable company. The Laysan Rail apparently made its last stand in the area around the exotic shrubs and lawns. This may, however, have been the result of better rat control in this area, rather than any particular advantages offered the rail by the habitat there.

Perhaps the only species that would not benefit, and might be harmed, by additional trees and shrubs are the Laysan and Black-footed Albatrosses and the Blue-faced Booby, all of which need strips of open area for landing and

for taking off. The albatrosses, despite the fact that they nest beneath clumps of shrubs, do not alight in the midst of the bushes; they always walk in to the nest from the nearest open space, although in some instances this distance is more than 100 feet. The widely spaced plantings of ironwood trees do not seem to reduce the number of Laysan Albatrosses nesting beneath them, perhaps because there is room to fly between the trunks and because the plantings are interspersed with roads, building areas, and other open spaces. However, if a great part of the surface were covered with dense, low-growing shrubs I think the number of Laysan Albatrosses would be reduced. Certainly the beach-loving Black-footed Albatrosses would not, under such conditions, invade the central areas of the islands as they now do. The Sooty and Gray-backed Terns might also be affected by more plant growth; on Midway, colonies of these birds seem to center in open spaces and simply overlap adjoining *Scaevola*-covered areas.

To establish successfully many of the exotic plants it was necessary to bring in soil. After 1906 the cable company brought in the equivalent of several shiploads (about 9,000 tons) of soil to get trees, shrubs, and grasses started around its compound. Later, soil was brought in to develop the nursery. The maintenance of a small farm with a few cows and chickens has added to the fertility of Sand Island. Not only has this soil been beneficial in producing a plant growth; it has also provided a topsoil better adapted to the needs of burrowing birds. It is not uncommon to see the burrows of petrels and shearwaters and the nests of albatrosses filled and covered by blowing sand in areas where there is neither humus nor plant roots to hold the sand. Burrows in pure sand collapse easily, trapping the birds; entrances to burrows of Bonin Island Petrels here are sometimes cone-shaped, 5 feet in diameter and 3 feet deep, caused by the constant sifting down and collapsing of the dry sand. It may be observed that where possible the birds select partly vegetated areas for burrowing.

Another act of man that will in the future help the birds is the addition to the area of the islands by filling with material dredged from the reef. Many acres of land have been created in this manner. At present only a few Laysan and Black-footed Albatrosses are using this new area which is barren of vegetation and has no topsoil. Further, it will take some time for the birds to extend their breeding areas to encompass this new region. Judging from other areas occupied by the various species the first forms to utilize this coral fill will be the albatrosses, Sooty Terns, and perhaps the Blue-faced Booby. As soon as low grasses appear the Noddy Terns and Gray-backed Terns will move in as they have already done on other parts of the island which have been reclaimed from war use. The Fairy Tern, Hawaiian Tern, and Red-footed Booby will not utilize the area until the *Scaevola* gets a good growth, nor will the Red-tailed Tropic Bird, which is a ground nester but is usually found beneath the *Scaevola*. It also is unlikely that Bulwer's Petrel and the Christmas Island Shearwater will nest on this hard-packed, smooth fill until some shrubs or piles of coral provide cover.

There are few reliable figures on the avian populations of Midway. Scattered notes on numbers of individuals of various species are to be found, but it was not until the "Tanager" Expedition visited Midway in April, 1922, that any attempt was made to secure data on the populations of all species inhabiting the atoll. In the period 1922 to 1941 no papers of any kind were published on the birds of Midway. Hadden (1941) gives incomplete estimates of some populations based on observations over a period of at least a year. Fisher and Baldwin (1946: 4) estimated the numbers of all species present in May, 1945; using the same method whenever possible, I took a census of all species present in December, 1946. It may be observed from this brief history that not only are there few census data available but that the data have not been secured in comparable months of the year and that no standard procedure has been



followed in estimating the populations. The results of the more extensive censuses mentioned above are presented in Table 1.

In this table the trend of populations can be observed in some species, but usually only in a general sort of way because different observers were involved and because allowances must be made for different months of the year. However, in many instances direct comparisons between the figures for 1922, 1945, and 1946 may be made. For example, the period of nesting and caring for the young in the albatrosses covers the months from November to May or June. Hence, data in any of these months can be used for comparative purposes, although one might expect that mortality from natural causes would reduce the number of adults in the latter part of the reproductive period.

The populations of both species of albatrosses, Bonin Island Petrels, Hawaiian Terns, Wedge-tailed Shearwaters, Red-tailed Tropic

Birds, and Gray-backed Terns increased greatly from 1922 to 1945 despite the adverse effects of the war. Of these the first four species showed considerable gains in the 18 months between the observations of 1945 and 1946. The table would seem to indicate an increase in the numbers of Christmas Island Shearwaters, Bulwer's Petrels, and Sooty Terns, but the month's difference in census dates is important; these species are just moving into the islands in late April and early May. This may explain the relatively few Sooty Terns found by the "Tanager" Expedition in 1922 and may explain the absence of Christmas Island Shearwaters and Bulwer's Petrels in April, 1922.

Populations of Blue-faced Boobies, Red-footed Boobies, frigates, and noddies have apparently never been abundant and there has been little change in numbers in the last 25 years. Noddies were much more abundant in December, 1946, than in May, 1945; this may be due

TABLE 1  
ESTIMATED NUMBERS OF BIRDS ON MIDWAY ATOLL\*

	WETMORE APRIL, 1922	GRANT APRIL, 1922	FISHER, BALDWIN MAY, 1945	FISHER DEC., 1946
Black-footed Albatross .....	4,000 N	5,000	53,000 N	69,000 N
Laysan Albatross .....	5,000 N	5,000	110,000 N	145,000 N
Wedge-tailed Shearwater .....	common	5,000	62,000 N	0
Christmas Island Shearwater.....	?	0	400 N	0
Bonin Island Petrel.....	many N	5,000	25,000 N	30,000
Bulwer's Petrel .....	?	0	600 N	0
Red-tailed Tropic Bird.....	20	300	19,000 N	25
Blue-faced Booby .....	2	—	3 N	5
Red-footed Booby .....	50 N	500	450 N	150
Brown Booby .....	12	500	0	0
Frigate (Bryan, 1902, saw 60).....	100 N	—	60	100
Mallard Duck .....	—	—	0	2
Laysan Rail .....	abundant	5,000	0	0
Pacific Golden Plover.....	many	1,000	250	2,500
Bristle-thighed Curlew .....	several	100	20	200
Ruddy Turnstone .....	common	5,000	350	9,000
Sanderling .....	0	0	0	2
Wandering Tattler .....	1	50	0	2
Gray-backed Tern .....	300 N	—	750 N	0
Sooty Tern .....	1,500	5,000	174,000 N	0
Noddy Tern .....	24	—	10	175 N
Hawaiian Tern (Bryan, 1902, saw 20) ..	few	100	2,100 N	2,500 N
Fairy Tern .....	fairly common	1,000	20,000 N	increasing daily
Domestic Pigeon .....	0	0	50 N	125 N
Domestic Canary .....	1,000	1,000	30 N	75 N
Laysan Finch .....	abundant	5,000	0	•0

\* N—indicates nesting on that date.

in part to a concentration for breeding in the winter, although the species nests the year round. Domestic Canaries decreased greatly in numbers from 1922 to 1945, but have since increased sharply. Domestic Pigeons transplanted sometime after 1922 are increasing rapidly. Two species, the Laysan Rail and the Laysan Finch, were abundant in 1922 and maintained this abundance until the late 1930's; rats probably accounted for the last individuals in early 1945. Brown Boobies were not seen in 1945 and 1946, but they have never been abundant on Midway.

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## *Paratylenchus minutus*, n. sp., a Nematode Parasitic on Roots<sup>1</sup>

MAURICE B. LINFORD, JULIETTE M. OLIVEIRA, AND MAMORU ISHII<sup>2</sup>

MEMBERS OF THE GENUS *Paratylenchus* Micoletzky (1921: 605–607) (Criconematinae, Anguillulidae) have been reported from soil samples taken about the roots of various plants and, less often, from within the root cortex from a number of localities in Europe, the British Isles, North America, and the Netherlands Indies; but nowhere has the abundance of these nematodes been sufficient to facilitate an investigation of their biology. Certain reports, including descriptions of two species, have been based upon individual nematodes. The most comprehensive and most recent paper on *Paratylenchus* is that of Goodey (1934), who concluded that the genus is monotypic and established *P. macrophallus* (de Man) Goodey as the type species. Although recognizing that some former workers had found this nematode within the cortex, Goodey determined that it occurred chiefly on the surface among the root hairs. He found one individual still attached by its stylet to the surface of a processed root. Goodey regarded this nematode as a semi-parasite, a term that seems to imply incomplete dependence upon the living root for sustenance.

Over a period of years in this laboratory a small representative of this genus that appears to be a distinct species has been taken in moderate numbers from soil samples from pineapple fields and has been found sparingly in or attached to the roots of pineapple plants and of various weeds (Oliveira, 1940: 368). Later

investigations have disclosed that it frequently is the most abundant nematode found about the roots of pineapple plants in certain old fields on the island of Oahu, Hawaii. Methods employed earlier had resulted in grossly underestimating its abundance: its very small size permits it to pass readily through the finest sieves suitable for separation of nematodes from soil suspensions, whether 200-mesh bolting silk or 325-mesh brass screen. Its predominantly ectoparasitic habit results in there being relatively few individuals within roots prepared for microscopic study, even if plants are grown in very heavily infested soil. Utilizing natural infestations, in which other nematodes of known pathogenic nature also occurred, we have investigated certain phases of the biology of this little parasite, including especially its feeding habits. We have not yet established, however, the pure cultures of this species that would be required to determine its significance as a pathogen.

### *Paratylenchus minutus* Linford, n. sp.

*Measurements*.—♀: 0.24–0.31 mm., mean 0.267 mm.;  $a=16-24$ , mean 19.1;  $\beta=3.4-4.1$ , mean 3.68;  $\gamma=12-18$ ;  $V=80-84$ ; stylet 16–21  $\mu$ . ♂: 0.22–0.27 mm., mean 0.258 mm.;  $a=22-27$ , mean 24.4;  $\beta=3.5-4.1$ , mean 3.82;  $\gamma=12-19$ , mean 14.4; spicula 16–19  $\mu$ ; tail 14–19  $\mu$ . Larvae: As small as 0.130 mm. long and 9  $\mu$  in diameter.

*Diagnosis*.—*Paratylenchus* of small size, with fine cuticular annulation interrupted by narrow lateral fields. Buccal stylet only moderately variable in length, degenerate in male. Esophagus

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<sup>2</sup>Pathology Department, Pineapple Research Institute. Juliette M. Oliveira is now Mrs. C. K. Wentworth, Editor, University of Hawaii.



proportionately long; degenerate in male. Excretory pore opposite anterior end of pyriform terminal bulb in living females; slightly posterior when killed. Anus in male protuberant; in female reduced to a faintly distinguishable pore three-fifths to two-thirds distance from vulva to terminus. No postvulvar uterine sac. Spicula slender, nearly straight through proximal four-fifths of length; almost equal in length to the proportionately short tail. Tail of male convex-conoid to the subacute terminus. Female body tapering behind vulva; tail dorsally conoid, ventrally subarcuate, variably subdigitate, with subacute terminus (Fig. 1).

*Type locality*.—Wahiawa, Oahu, Hawaii.

*Type host*.—*Ananas comosus* (L.) Merr. (pine-apple).

*Comparisons*.—In size and proportions our specimens closely resemble *P. besoekianus* Bally and Reydon (1931: 92–94). This led to an earlier identification of our material with that species (Oliveira, 1940: 368). *P. minutus* differs, however, in lack of a postvulvar uterine

sac and in a shorter terminal bulb. Major differences occur in size and form of spicula and gubernaculum, and in the male anus.

*P. minutus* is distinctly smaller than *P. bukovinensis* Micoletzky (1921: 606), *P. nanus* Cobb (1923: 367), and *P. macrophallus* (de Man) Goodey (1934: 80). From the latter it differs also in its less variable stylet length. Lateral fields bearing four faint incisures are in agreement with *P. nanus* but not with *P. anceps* Cobb (1923: 370). None have been described for the other species.

Males of *P. minutus*, which usually are as abundant as females in extracts from moist soil about roots, are distinctly smaller than those described by Goodey and tend to be more slender and to have proportionately shorter and less acute tails. Spicula and gubernaculum, although smaller, agree well in form with Goodey's 1934 figure 3. The protuberant anus of *P. minutus* distinguishes it from both *P. besoekianus* and *P. macrophallus*, the only species for which males have been described. A

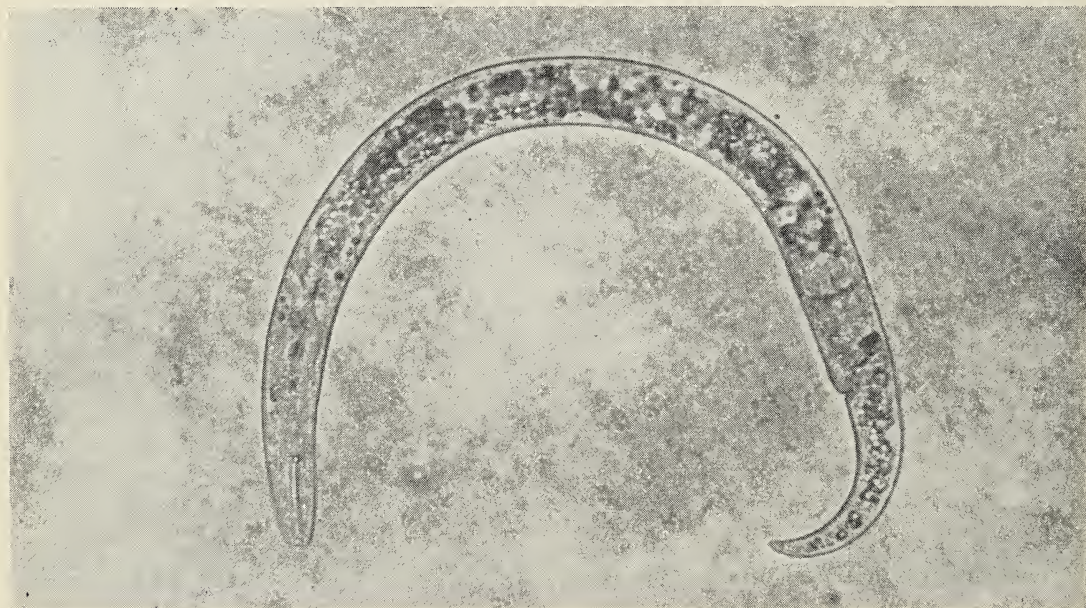


FIG. 1. Female of *Paratylenchus minutus* relaxed in water. Observe the relatively long stylet, the large median bulb, the characteristic distribution of fat globules especially in walls of the intestine, the light-appearing sperm mass in the uterus, and the abrupt narrowing of the body at the vulva.  $\times 570$ .



similar anus has been illustrated for *Criconea squamosum* (Cobb, 1913; Taylor, 1936, pl. 46, fig. 11). In lateral view this appears as two narrow lip-like projections about  $1\mu$  wide that extend somewhat backward about  $1.5\mu$  or one-fifth the width of the body at this position. This character is best seen when the spicula are retracted, although the posterior lip can be distinguished when they are protruded.

#### OCCURRENCE

We have collected this little nematode from three islands of the Hawaiian group: Oahu, Molokai, and Maui. On Oahu it occurs widely and abundantly in pineapple fields in several districts but not in all of the fields where pineapples have long been grown. On Molokai it has been taken from a single pineapple field location among 16 sampled. On Maui it has not been found in a number of pineapple field samples, but it was taken from the roots of

mixed vegetation at elevations of 4,100 and 6,700 feet above sea level. Other habitats generally have not been searched. Limited sampling from mixed vegetation and grasslands adjacent to heavily infested pineapple fields on Oahu, however, has produced few individuals of this species, which suggests that the pineapple field environment is especially favorable to it.

Because of its small size and ectoparasitic habit this paratylench is readily overlooked. We first became aware of its abundance when we found large numbers of these parasites attached to pineapple rootlets that had been fixed, cleared, and stained without washing (Linford, 1942b: 97–100). (Fig. 2.) Because their size permits most of them to be lost through the finest sieves, we adopted the Baermann funnel technique or modifications of it for extraction from roots and soil. In one comparative test, decanting and wet screening recovered 16 paratylenchs per gram of soil, all of them adult females, but the

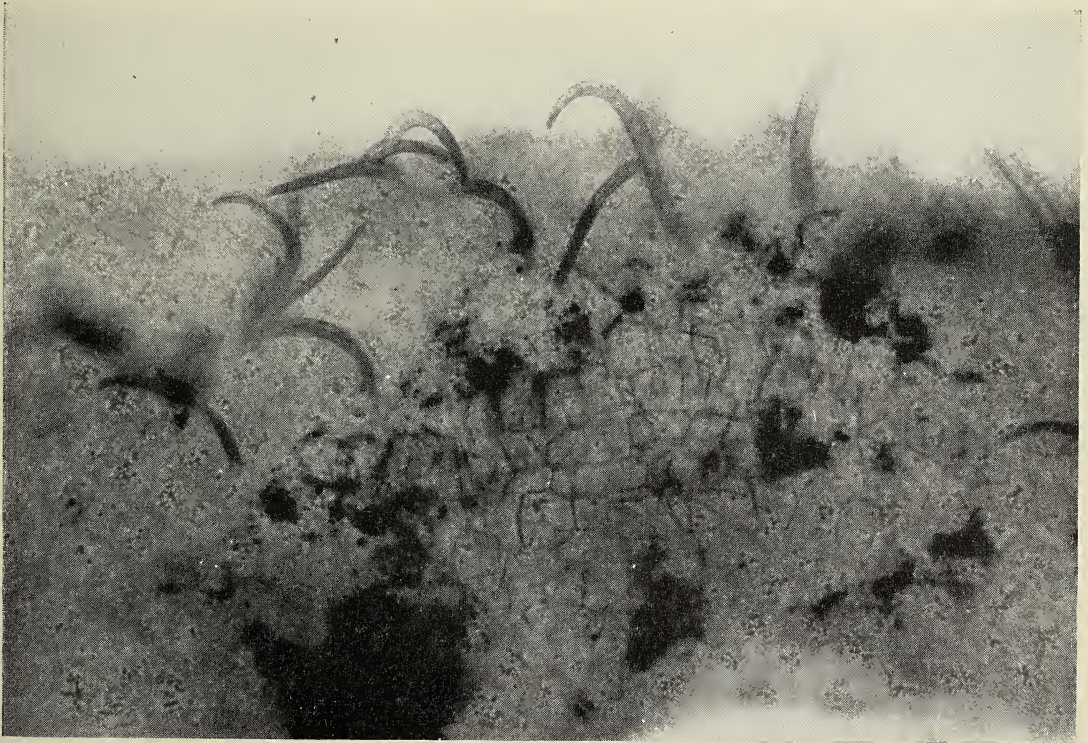


FIG. 2. Numerous *Paratylenchus minutus* projecting from a fixed and stained pineapple rootlet. Most, if not all, of these nematodes were attached only by the buccal stylet. Crescentic posture is typical of this species when relaxed or dead.  $\times 175$ .



Baermann method extracted 209 males, females, and larvae per gram. To retain the soil while allowing small nematodes to crawl through, we have used a fine-textured grade of paper towel that retains its strength when wet.

Soil from under pineapple plants in old fields frequently contains 100 or more paratylenchs per gram. Two samples from separate fields have yielded over 900 per gram. These nematodes are particularly numerous in immediate association with roots. Four composite samples of unwashed roots from each of two fields were held in extraction funnels for 48 hours, then the heaviest nematode population from each field was selected for closer study. The extracted roots were washed free of soil, blotted, weighed, and measured. From one sample, paratylenchs were obtained at rates of 23,800 per gram of root or 570 per centimeter of length. Soil from this source yielded 266 per gram. From the other field, paratylenchs numbered 23,500 per gram of root or 600 per centimeter of root length, and 258 per gram of soil. These and the remaining six samples contained much smaller numbers of other plant parasites in addition to predaceous species of *Aphelenchoides* and *Dorylaimus* (see Linford, 1937a: 42-44, and Christie, 1939).

Within fields, populations sometimes are highly variable, even from plant to plant, but if this nematode is pathogenic to pineapple its effects are overshadowed by other injurious factors, for no apparent correlation exists between populations of paratylenchs and growth vigor of the plants. Very heavy populations are sometimes found around the roots of strong plants.

#### TOLERANCE TO ADVERSE CONDITIONS

Extraction of numerous paratylenchs from dry, loose soil in September in a field that was almost ready for planting after having been plowed several times suggested that this nematode was tolerant to desiccation. Naturally infested soil selected for laboratory tests was of fine texture, with a wilting point in the vicinity

of 27 per cent moisture. When first sampled, at 30.7 per cent moisture, it contained numerous females, males, and larvae. After drying to 20 per cent moisture in 5 days these were only slightly less abundant. At 16.3 per cent moisture, males and larvae were more reduced in numbers than were the females. No living males were recovered at 10.0 per cent, the next drier sample tested. A few larvae were recovered at 9.4 per cent but not at 7.5 per cent. Females revived sparingly after the soil had dried to 7.5 per cent and 7.2 per cent but not to 6.3 per cent moisture. There is no assurance that drying was sufficiently gradual in these tests to measure the maximal degree of tolerance to desiccation. The data are adequate, however, to demonstrate that natural desiccation in the field is not likely to eradicate this nematode, for it occurs in subsoil to a depth of 18 inches or more where drying is much less extreme than near the surface.

Limited information on the sensitivity of *P. minutus* to soil fumigants has been obtained from experiments concerned chiefly with the root-knot and reniform nematodes. Roots of cowpea or tomato grown as indicator plants were washed rapidly from their pots and then held in dishes of shallow water 18 hours or longer before being examined for galls and egg masses. Microscopic examination of the sediment in such dishes frequently detected sufficient paratylenchs for comparative scoring, although the method seriously underestimates populations of this species.

Data collected in this way from laboratory fumigation tests have indicated *P. minutus* to be almost equal to *Heterodera marioni* in sensitivity to various samples of D-D mixture, chloropicrin, and ethylene dibromide. It sometimes has appeared slightly more tolerant. In field tests, following injection of 200 pounds of D-D mixture per acre under mulch paper, this nematode, like other species, has not been recovered from soil samples taken before planting. After 2 years of pineapple growth, however, it has been found even where the soil had been fumigated with 400 pounds per acre or, in one test, with 600



pounds. Survival in subsoil or in non-fumigated spaces between beds, or both, is the probable explanation. Similar reinfestation occurs with other nematodes.

#### PARASITIC HABIT

*Paratylenchus minutus* is chiefly ectoparasitic in the young mature zone of roots. This has been determined by microscopic examination of the undisturbed association of living nematodes with roots, utilizing methods described in detail elsewhere (Linford, 1942*b*). Briefly, roots are grown in infested soil or other fine granular media against a thin coverslip and are then examined under the compound microscope with incident light. A 40 $\times$  water-immersion objective lens permits useful magnifications up to 600 diameters. This method of study has defined the general patterns of the feeding process and of host response. Microscopic examination of stained and cleared roots has yielded information on occurrence within roots.

Paratylenchs are attracted to the piliferous zone where, typically, the larvae and females remain on the surface to feed by inserting the stylet tip into epidermal cells or root hairs (Fig. 3). Males often are observed among them but are unable to feed. The process of puncturing a cell wall has not been observed; but it probably is accomplished rapidly, in contrast with the somewhat prolonged effort required by larvae of *Heterodera marioni* (see Linford, 1942*a*: 582), because few tentative thrusts of the paratylench stylet have been seen. The majority of nematodes found with the stylet tip inserted into a cell have been in process of feeding as shown by rhythmic pulsation of the median esophageal bulb, with its valve opening and closing rapidly.

Periods of sucking alternate with and are preceded by periods of rest during which the median bulb is inactive or only twitches occasionally. Such periods may vary from a few

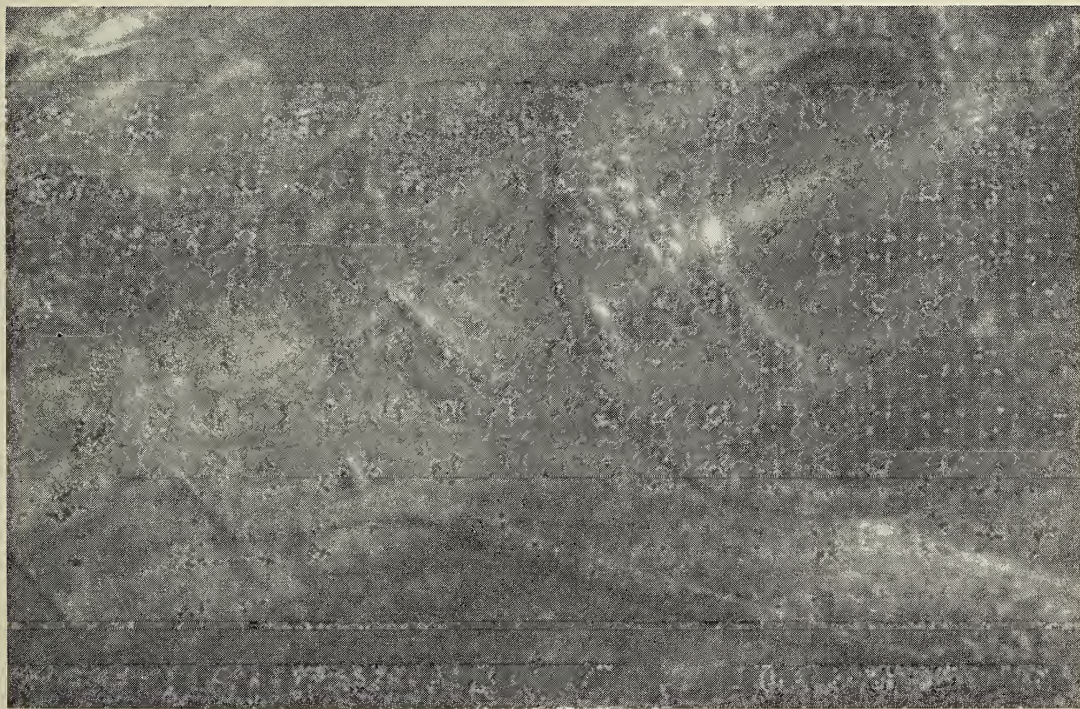


FIG. 3. Two *Paratylenchus minutus* feeding on root hairs of cowpea growing against the coverslip in an observation chamber. Both nematodes have their stylet tips inserted into living root hairs.  $\times 1,500$ .



minutes to over 2 hours. The sucking process also is of long duration, continuing without interruption in some individuals for well over an hour, but it may be interrupted and resumed many times without the nematode's moving to another feeding site. Pulsation of the bulb is vigorous and readily observable even in young larvae, but beyond seeing that the valve plates are pulled well apart and then come back together at each beat it has not been possible to analyze the motion. The rate is variable between individuals, commonly ranging between 80 and 200 beats per minute. Minor irregularities and an occasional beat that may represent a different action of the valve are sometimes seen.

Many observations of host cell protoplasts indicate that no great disturbance results during or soon after feeding. Root hairs are especially favorable for such studies but the active protoplasts of epidermal cells may often be seen when the object is appropriately oriented to the source of light and when the root surface is clean. When the stylet is first inserted, its tip probably extends through the cytoplasmic envelope into the central vacuole. It soon becomes surrounded by a dome of granular material delimited by what appears to be a very thin membrane. During pulsation of the median bulb, this dome enclosing the stylet tip shows synchronous pulsation. Otherwise it is motionless, and no flow from or into the stylet has been detected.

Whether the nematode is sucking or lying at rest, and whether one, two, or even three are feeding simultaneously from a single cell, protoplasmic streaming of apparently normal nature and rate continues without interruption. Sometimes the nucleus moves to a position near a stylet tip; occasionally the dome of cytoplasm over the tip appears to be a focus of streaming strands of cytoplasm; but more commonly the stylet tip and its surrounding mass appear to be only a minor obstruction past which the cytoplasm flows. This has been true of the several host species studied in detail. Streaming continues also after the stylet is retracted and

the nematode moves away. Even after a female had fed from one cell or a small group of cells of a pineapple root long enough to lay 13 eggs, no definite pathology could be distinguished. Very heavily parasitized roots of cabbage seedlings grown in fine sand, fixed, cleared, and stained have shown as many as six larvae and females all with their stylets in a single epidermal cell, without any conspicuous alteration of its protoplast.

This paratylench appears to be relatively sedentary once it has begun to feed in a suitable cell, for certain nematodes in marked locations have been observed during several days to be feeding either in the same cell or in cells lying close together and with the body position changed only moderately. One well-isolated female feeding on pineapple roots was found with a loose cluster of four eggs. Four days later there were 12 eggs. The following day there were 13, and the nematode lay free in the soil with its stylet retracted. Another female apparently laid 11 eggs in two loose clusters very close together, and was still feeding after these had begun to hatch. Between the sixth and seventh days of observation, two larvae began to feed very close to empty egg membranes of one of these clusters.

Observation of the living material gives the impression that this paratylench is strictly ectoparasitic, for the feeding of many individuals during prolonged periods may be observed without detecting any attempt to use the stylet to break down a cell wall or otherwise to force an entry. When roots that have been stained and cleared are examined, however, females, young, eggs, and even a few males may be found within epidermal cells or located either within or between cells of the cortex. These always are few in proportion to the numbers that were present on the root surface, and many if not all of them entered through wounds made by other agencies. Wounds made by emergence of lateral roots allow entry into intercellular spaces deep within the cortex. Sharp sand particles between root and glass in observation



chambers sometimes slit the elongating root, and paratylenchs enter freely. Cracks in the surface of enlarging galls caused by *Heterodera marioni* have been seen to serve in the same way. Entry into epidermal and cortical cells sometimes occurs through penetration wounds made by two species of nematodes consistently present in the soil used in these studies, *Rotylenchulus reniformis* Linford and Oliveira (1940) and a transient rotylech formerly reported from this laboratory as *Rotylenchus multicinctus*. Both species perforate cortical cells as they penetrate somewhat radially to the stele. They sometimes break into an epidermal cell and then move on to another location before penetrating more deeply; and the transient rotylech may penetrate deeply, then withdraw, and move to another site. That some of these wounds are utilized was clear when as many as three paratylenchs were found entering at the side of a single larger form. Many and perhaps most of the paratylenchs found within the epidermis and cortex appear to have entered through one or another of these types of wounds.

#### HOST RANGE

During investigations of feeding habits it became apparent that *Paratylenchus minutus* is able to feed upon roots of a wide range of plants because the feeding process was observed on every plant species that was subjected to adequate observation. No attempt to determine the limits of the host range therefore seemed worthwhile. A few additional species of weeds, crop plants, and ornamentals were grown in miniature root-observation boxes of infested soil and, as before, feeding was observed on all of them that developed sufficient healthy roots in a position suitable for observation. Roots of a few species were stained and cleared and, in some of them, eggs were found associated with females within the cortex. These plants are marked with an asterisk in the list that follows. Plainly this nematode is able to obtain from these plants and also from pineapple plants sufficient nutrient to reproduce. The conditions of

these observations are such, however, that it would be misleading to list plants so examined in which eggs were not found, for the plants were all young, numbers of nematodes within the roots were few, and, judging especially from the pineapple, which was studied in more detail than other hosts, most of the eggs are laid free in the soil or on the root surface.

- Ananas comosus* (L.) Merr.: Pineapple
- Avena sativa* L.: Oat, Vicland
- Bidens pilosa* L.: Spanish needle
- Brassica oleracea* L. var. *capitata* L.: Cabbage, Golden Acre
- Cucumis sativus* L.: Cucumber, Long Green
- Cucurbita Pepo* L.: Squash, White Bush
- \**Emilia sonchifolia* (L.) DC.: Flora's paintbrush
- \**Eschscholzia californica* Cham.: California poppy
- Euphorbia geniculata* Ortega
- Polygonum Fagopyrum* L.: Buckwheat
- Helianthus annuus* L.: Sunflower, Mammoth Russian
- Hibiscus esculentus* L.: Okra, Tall Green
- Medicago sativa* L.: Alfalfa, Chilean
- Oxalis corniculata* L. var. *viscidula* Wieg.: Sticky sorrel
- Portulaca oleracea* L.: Purslane
- \**Phaseolus aureus* Roxb.: Mung bean
- Phaseolus lathyroides* L.: Wild pea-bean
- Raphanus sativus* L.: Radish, Scarlet Globe
- Richardia brasiliensis* (Moq.) Gomez: Richardsonia, false ipecac
- Tagetes erecta* L.: Marigold, Guinea Gold
- Tricholaena repens* (Willd.) Hitchc.: Natal grass
- \**Triticum aestivum* L.: Wheat, Henry
- Vigna sinensis* (L.) Savi: Cowpea, Whippoorwill
- Zea Mays* L.: Corn, maize
- \**Zinnia elegans* Jacq.: Zinnia, Cut-and-Come-Again

#### DISCUSSION

The lack of visible pathology in cells fed upon, and the occurrence of large populations upon roots of apparently normal pineapple plants, tend to indicate that this paratylench is non-pathogenic. Such a conclusion would be premature with present evidence. All observations reported here have been of relatively short duration, and experimental tests of pathogenicity can be made only after pure cultures of this species have been developed, free from other nematodes and root-invading fungi that have been associated with it in these studies.

The pineapple plant is slow to respond to root injuries and, under Hawaiian conditions at least, populations of other nematodes may be markedly reduced by biological agents after they have inflicted root damage but before top growth shows the effect. Lack of correlation between abundance of paratylenchs and plant condition is therefore not proof of harmlessness. It seems improbable that such populations as are encountered around pineapple roots could obtain their entire sustenance from the roots without in some way altering absorptive action or speeding senescence if not even altering the physiology of the entire plant.

Regardless of any minor or delayed pathological effects of its feeding, this paratylench obtains its food without immediately endangering its food supply. It may therefore be considered a well-adjusted parasite. The precise way in which it obtains its food from cells that characteristically are highly vacuolated remains undetermined. By analogy with the predaceous *Aphelenchoides* and the gall-inciting *Heterodera marioni* (Linford, 1937a: 42-44; 1937b; 1942a) the periods of rest of the esophageal bulb, alternating with periods of rapid pulsation, are presumably periods of injection into the host of glandular secretions that selectively prepare nutrients for ingestion. Saliva of predaceous aphelenchs, however, is vigorously digestive, and that of the root-knot nematode stimulates profound changes in the protoplasts of cells into which it is injected in addition to any function it may perform in reducing some of the protoplasm to a state suitable for passage through the narrow lumen of the stylet. In both of those types of nematode the quantity of saliva is relatively copious, and it must distribute freely to perform its functions. In the paratylenchs, however, with small esophageal glands, one would expect the saliva to be limited in quantity or to be secreted only slowly. It is not remarkable, therefore, in view of the minute size of these nematodes and of the limitations placed upon microscopic study by illumination only with incident light, that no flow of saliva

has been detected. Neither could ingestion of food be seen under these conditions even though it obviously occurred during pulsation of the bulb. Unfortunately it was not possible to determine whether the granular accumulation around the tip of the stylet consists only of host cytoplasm or, in part, of secretions from the nematode. That it is not wholly normal cytoplasm was indicated by the temporary persistence of at least part of the mass for a time after the stylet had been withdrawn. If a small quantity of saliva is injected it could probably function to the greatest advantage and with the least disturbance of the host if it remained localized close to the stylet, acting upon cytoplasm clumped about the stylet, rather than distributing throughout the proportionately large host cell. Indicative of extra-oral digestion is the lack of a functional anus and of discernible fecal material in the rectal region. This is in sharp contrast to various other nematodes of somewhat comparable size but different food habits in which discharges of fecal material are readily detected. Even with selective ingestion of almost wholly utilizable nutrients, however, there should be a great excess of water to be excreted. Perhaps this is discharged unnoticed through the excretory pore, carrying with it all soluble waste materials.

There seems no doubt that *Paratylenchus minutus* is an obligate parasite, obtaining all of its nutriment from living cells, yet this fact is not readily determinable by any means other than direct observation of the living nematodes in association with roots. Greater abundance of nematodes near roots than in soil remote from them is not a valid criterion of parasitism, because various microphagous and predaceous nematodes similarly congregate in the rhizosphere where their food is most abundant. Dead rootlets, killed by fungi or other agents, soon are invaded by non-parasitic forms. Similarly, occurrence of moderate numbers of a species within relatively sound roots is not evidence of parasitism since microphagous forms, working over the root surface, may enter



through wounds as does this species. Even infusoria have been found in punctured root cells. There seems, accordingly, to be no substitute for microscopic observation of the living nematodes in association with roots for determination of feeding habits and host ranges of species found superficially associated with roots.

Our studies raise some question concerning the syngonism reported for *Paratylenchus nanus* by Cobb (1923: 369) and Steiner (1924: 1065). Those workers regarded the species as syngonic because, in the absence of males among their specimens, the females consistently contained sperm cells in the uterus. Abundance of males in *P. minutus* makes such an assumption unnecessary. Furthermore, our experience leads us to question whether males may actually have occurred in the populations from which Cobb and Steiner drew their samples. We first recognized the abundance of males after discarding sieve methods of collection and adopting the funnel technique; and the inability of males to feed results in relatively few of them entering a root. Before syngonism is accepted for any paratylench there should be either better evidence that males do not occur or that the female is capable of spermatogenesis.

#### SUMMARY

A very small nematode that occurs in great abundance in certain pineapple fields on the island of Oahu, and less widely on Molokai and Maui, is described as *Paratylenchus minutus* Linford. Over 900 individuals have been extracted from 1 gram of soil and over 23,000 per gram of pineapple root with its adhering soil. This nematode is relatively tolerant of slow desiccation in soil but is essentially equal to *Heterodera marioni* in sensitivity to soil fumigants. It is primarily an ectoparasite of the root hairs and epidermal cells of the young mature zone of roots, but it enters the epidermis and cortex through wounds made by other agencies. To feed, it inserts the tip of its stylet through a wall into a living cell. In this position, prolonged periods of pulsation of the median esophageal bulb for ingestion of food are preceded by and alternate with periods of rest. This feeding, which appears to involve

extra-oral digestion, fails to interrupt normal streaming of the host protoplast. No visible pathology has been associated with prolonged feeding from a single cell. The host range of this paratylench evidently is wide, for limited observation has established 25 known host plants representing 13 families.

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## The Origin and Composition of Pyrolusite Concretions in Hawaiian Soils<sup>1</sup>

G. DONALD SHERMAN, ANNIE K. S. TOM, AND CHARLES K. FUJIMOTO<sup>2</sup>

THE SOILS of the drier regions of the Hawaiian Islands have a very high manganese content. Kelley (1909) has reported that certain dark-colored soils which are closely associated with the red soils have an  $Mn_3O_4$  content ranging from 2.4 to 9.7 per cent. He has indicated the relationship between the poor growth of pineapples and the high manganese content of these soils (1909, 1910). In a later publication Kelley (1912) described the occurrence and distribution of the manganiferous soils on the island of Oahu. He pointed out that within the boundaries of the manganiferous soils there were areas of variable sizes where pyrolusite concretions appeared to have accumulated. These areas have been observed by many workers since the publication of Kelley's work. In some of the irrigation ditches it is possible to gather large numbers of these concretions which have been concentrated by the irrigation water.

The origin of these concretions has been the subject of much speculation. Kelley (1912) has suggested two possible hypotheses. The first states that the formation of the concretions took place while the island of Oahu was submerged. This theory is supported by the similarity between the chemical composition of the concretions found in the soils of the island of Oahu and the composition of concretions from the floor of the Pacific Ocean as reported by Murray and Renard (1891). Pyrolusite concretions are often found in the sediments of fresh-water lakes. The

second theory of the origin of these concretions is that the manganese has become soluble by the weathering of the basalt lavas and has leached to the lower elevations in drainage waters where it becomes oxidized and is precipitated around various nuclei.

During the summer of 1947 the senior author discovered a large number of pyrolusite concretions formed around the roots of a shrub on the island of Lanai. A closer examination revealed that a thin layer of  $MnO_2$  had been deposited around all of the roots and that concretions had developed at certain points along the root of the plant. The concretions, when separated from the root of the plant, were tubular in shape. Further examination of the concretions in the soil revealed that the majority of them had been formed by their precipitation around roots of plants. As a result of this discovery a study has been made to determine the nature, origin, and composition of pyrolusite concretions occurring in Hawaiian soils.

A number of concretions have been collected from several typical manganiferous soils. In each case evidence was gathered as to the possible origin of the concretion. From these examinations it is very likely that all of the concretions have been formed by the oxidation of soluble manganese and its precipitation around nuclei. The deposition of  $MnO_2$  occurs in root channels, in cracks in the soil, around roots of plants, on surfaces of soil granules, and in the non-capillary pores of the soil. The shape of the concretion is determined by the manner of deposition. The spherical forms have developed where the  $MnO_2$  has been oxidized and depos-

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<sup>2</sup> University of Hawaii Agricultural Experiment Station, Honolulu, Hawaii.



ited around very small nuclei. The size of the spherical concretions varies from barely visible specks to perfectly rounded balls three-eighths of an inch in diameter. The nature of the growth of these concretions prevents the inclusion of the surrounding soil. In general this type of concretion is scattered uniformly throughout the soil. The concretions which form in root passages, earthworm holes, cracks, and around soil aggregates have irregular shapes. These concretions are rough and have no definite shapes. Some of the concretions formed in this manner do include portions of soil. As mentioned before, the concretions forming around roots have a tubular shape. They are irregular in length and diameter. When the root decays, the opening becomes filled with soil; however, the concretion will continue to grow with the gradual displacement of the soil from the opening. The three types of concretions are shown in Figure 1.

The chemical composition of the mangani-

ferous soil and its concretions was determined by procedures described by Piper (1944). The data obtained from this analysis are given in Table 1. The manganese oxide contents of the three soil samples are very variable; otherwise their chemical composition is quite uniform. The concretions have a very uniform composition. The silica and iron oxide content of the concretions is lower than that of the soil. The alumina content of the concretions would suggest that they contain variable amounts of clay, which in the case of these soils would be of the kaolinite type. The  $\text{MnO}_2$  content of the concretions is uniform, varying from 27.9 to 30.8 per cent.

The data given in Table 2 were obtained from the analyses of typical concretions of the spherical, tubular, and irregular types. The chemical composition of the three types of concretions is in general similar. The total oxides are higher in the spherical form, suggesting either



FIG. 1. Types of pyrolusite concretions found in Hawaiian soils. Lower left, spherical type; upper center, tubular, formed around roots of plants (a black thread has been passed through the cavity left by a decayed root); lower right, the irregular type formed in the larger openings in the soil.

TABLE 1

THE CHEMICAL COMPOSITION OF SOME MANGANIFEROUS SOILS AND PYROLUSITE CONCRETIONS SEPARATE FROM SAME SOILS

SAMPLE	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	MnO <sub>2</sub>
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
MANGANIFEROUS SOILS					
Soil No. 1.....	31.32	32.00	16.10	2.90	2.58
2.....	31.72	36.60	16.55	2.85	5.22
3.....	31.28	36.90	16.20	2.90	1.79
CONCRETIONS FROM SOILS					
Concretion 1.....	19.87	33.78	10.74	1.56	28.04
2.....	17.54	26.23	11.15	2.02	30.03
3.....	17.38	25.70	13.70	2.34	30.78
4.....	18.91	27.07	10.88	1.55	30.18
5.....	16.83	29.36	9.85	2.29	29.88
6.....	15.80	31.34	12.69	1.33	27.93
7.....	16.86	28.37	13.25	1.33	28.63

TABLE 2

THE CHEMICAL ANALYSES OF DIFFERENT TYPES OF PYROLUSITE CONCRETIONS FOUND IN HAWAIIAN SOILS

TYPE OF CONCRETION	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	MnO <sub>2</sub>
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Spherical					
1.....	15.88	33.12	14.20	2.65	31.13
2.....	16.67	32.26	14.26	2.61	29.45
3.....	17.27	32.73	4.47	1.65	33.96
4.....	21.24	28.92	9.16	2.26	29.39
5.....	19.94	29.92	7.47	1.91	34.16
6.....	11.21	31.89	9.46	2.18	34.02
7.....	14.38	39.76	0.66	2.63	39.76
Average.....	16.66	32.66	8.53	2.27	33.12
Tubular					
1.....	11.64	25.60	18.66	2.74	23.83
2.....	14.53	24.86	16.73	2.39	28.73
3.....	9.50	33.10	17.77	3.22	23.13
4.....	10.82	30.59	16.05	2.61	24.78
5.....	15.93	26.25	11.54	2.71	31.09
6.....	17.14	31.94	11.37	2.79	26.30
7.....	15.68	27.81	10.57	2.22	31.37
Average.....	13.61	28.59	14.67	2.79	27.03
Irregular					
1.....	10.95	34.13	4.76	2.38	25.11
2.....	14.33	29.08	6.24	2.27	28.06
3.....	13.06	15.29	8.12	1.88	44.19
4.....	17.54	24.97	15.15	3.37	28.90
5.....	17.96	25.82	13.44	3.31	30.82
6.....	19.79	26.67	10.06	2.24	32.70
Average.....	15.60	26.00	9.63	2.57	31.63



less water of hydration or a greater purity in the minerals making up the concretions. It would appear that the composition of the pyrolusite concretions is not affected by the type of deposition since there is greater variation between individual concretions within the type than between the types.

The nature of the deposition of the  $MnO_2$  around certain specific nuclei rules out the submergence hypothesis of origin. The formation of the concretions has been the result of soil weathering since they have been precipitated in those soils which have developed under alternating wet and dry conditions. The alternating wet and dry condition of the soil is essential in the development of concretions of pyrolusite and ferruginous-pyrolusite concretions since it provides the conditions for the solution, leaching, oxidation, and precipitation of the manganese which are necessary for the process. Kelley (1912) has pointed out that pyrolusite concretions are not found in soils which received sufficient rainfall to keep the soil in a moist condition throughout the year.

#### SUMMARY

Pyrolusite concretions are found in small areas within the manganiferous soils, the red soils, of the Hawaiian Islands. These concretions are found in the soils of the drier regions which have definite wet and dry seasons. The origin of the pyrolusite concretions in these soils has been the subject of some speculation. Two

hypotheses have been proposed: namely, that the concretions were developed during a period of submergence of the islands, and that they have developed as a result of the weathering of lavas at higher elevations and the subsequent leaching of the manganese to lower elevations where it has been precipitated.

Pyrolusite concretions have been found which have developed around the roots of a shrub. An appreciable portion of the concretions found in Hawaiian soils has been developed by the deposition of  $MnO_2$  around the roots of plants. Further studies suggest that the spherically shaped concretions have been formed by the deposition of  $MnO_2$  around very small nuclei. The irregularly shaped concretions have been deposited in cracks in the soil, earthworm burrows, and larger openings in the soil.

The concretions have been analyzed; their  $MnO_2$  content varies from 23.1 to 44.2 per cent.

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## New Sponges from the Yap Archipelago

M. W. DE LAUBENFELS<sup>1</sup>

THE YAP ARCHIPELAGO is located east of the Philippines, in latitude  $9^{\circ}35' N$  and longitude  $138^{\circ}15' E$ . It is basically of rocky formation with an extensive fringing reef of live coral, which encloses a lagoon-like harbor and tidal-flat region at each end of the small archipelago.

In the summer of 1946 R. W. Hiatt of the University of Hawaii collected invertebrates, especially decapod crustaceans, in and about Yap. On two species of dromiid crabs he found interesting new species of sponges. He also collected a third species of sponge which is probably not a new species.

### *Spongosorites porites*, new species

The holotype of this species is catalogue number 22732 of the United States National Museum.

This was collected in July, 1946, by R. W. Hiatt, on a dromiid crab of the genus *Cryptodromia*, found in holes in dead coral on tidal flats in Tomil Harbor, on the island of Yap.

*Shape*: A smoothly rounded mass.

*Size*: Approximately 10 mm. thick, 15 mm. in diameter.

*Color*: Black. In many sponge species there are many cells with darkly pigmented granules located within 1 mm. or less of the surface of the mass or right at it. In *Spongosorites porites* such cells are rather uniformly distributed throughout the sponge although they are somewhat more densely grouped near the surface.

*Consistency*: Weakly spongy.

*Surface*: Smooth to the naked eye, microscopically felted.

*Oscules*: Barely visible to the naked eye, probably close to 300 microns in diameter when fully opened, in life. About a dozen on the specimen.

*Pores*: Microscopic, contractile, chiefly closed in the specimen.

*Ectosome anatomy*: As in the Haliclونidae, and to a lesser extent in some Axinellidae, there is practically no dermal specialization. The rather dense endosome extends to and forms the surface. In many places there is a region about 100 microns thick, right at the surface, where there is a confusion of many spicules but no flesh. This may be an accidental condition. No subdermal space could be found.

*Endosome anatomy*: The flesh is dense, with a preponderance of heavily pigmented granules. The spicules are also densely crowded, so that very little cavity of any sort remains.

*Skeleton*: The abundant spicules are practically all oxeas. An occasional rounded end is almost certainly accidental. The megascleres are all close to 6 by 300  $\mu$ . The microscleres range from 2 by 50 to 3 by 75  $\mu$ , and often have a single bend in the middle, so that they vaguely resemble toxas.

*Discussion*: Topsent (1896: 117) established the genus *Spongosorites* for the one species *placenta*. This came from a depth of 550 meters in the Atlantic Ocean near the Azores. As compared to *porites*, it is paler, harder, and the smaller category of spicules has a size range about 5 by 70  $\mu$ . Topsent also describes the

<sup>1</sup> Department of Zoology and Entomology, University of Hawaii. Manuscript received July 3, 1948.



occurrence of centrotylote spicules, but it is not clear if these should be regarded as diagnostic; probably they are merely the sort of malformation that is known to be likely.

Subsequently many sponge species have been referred to *Spongisorites* because of their content of larger and smaller oxeas without definite intermediates, but these species have been radiate in architecture, with huge megascleres, thus clearly epipolasid in nature. In various places in my publications I have transferred all of them to other genera, except, of course, the genotype and one other species that Hallmann had already transferred. Thus it appears that this sponge from Yap is the second specimen of a *Spongisorites* that is available for consideration. The genus *Topsentia* has a spiculation of oxeas for megascleres, with microxeas for microscleres, but it has a definitely separable, tangent dermis, over subdermal cavities, and apparently sponges of this sort have never been confused with *Spongisorites*.

Special mention may be made of *Spongisorites suluensis* Wilson (1925: 331) from the Philippines, because of the proximity to Yap. This was made the type of the genus *Epipolasis* by de Laubenfels (1936: 162). It is a clearly epipolasid sponge, with huge oxeas 32 by 1,350 microns, and the microscleres are ultra-thin trichodragmas rather than toxa-like microxeas. It thus belongs in at least a different family, even a different order, from the proper type of *Spongisorites*, although it appears to answer the words of the diagnosis of the genus *Spongisorites*.

The pigment distribution in *S. porites* is unusual. The other characteristics, both of this species and of its genus, are all separately commonplace, yet the evidence shows that the particular combination of these traits is extremely rare.

### *Chondrilla euastra*, new species

The holotype of this species is catalogue number 22731 of the United States National Museum.

This was collected in July, 1946, by R. W. Hiatt, on a dromiid crab of the genus *Cryptodromiopsis*, found under coral blocks on sand flats on the northeast shore of the island of Map.

*Shape*: A smoothly rounded mass.

*Size*: 7 by 10 by 14 mm.

*Color*: Black exterior, dark gray interior.

*Consistency*: Cartilaginous, a stiff jelly.

*Surface*: Smooth to the naked eye. Even under the microscope the irregularities appear minute.

*Oscules*: Now 200  $\mu$  in diameter, probably somewhat larger in life, 3 to 5 mm. apart.

*Pores*: Microscopic, contractile, closed.

*Ectosome anatomy*: There is a dense organic surface layer which contains ameboid cells but seems to be largely gelatinous material. The cells with darkly pigmented granules are chiefly within 100  $\mu$  of the surface but a few are scattered in the deeper tissues.

*Endosome anatomy*: Dense, but with the usual architecture of canals and chambers within the basal jelly. Many canals are about 150–200  $\mu$  in diameter. The flagellate chambers are round, 25  $\mu$  in diameter.

*Skeleton*: In addition to the ubiquitous jelly, there are scattered euasters, 18  $\mu$  in diameter. These consistently have no centrum, or so little that its presence is dubious.

*Discussion*: The genus *Chondrilla* was established by Schmidt (1862: 39) for the species *nucula* and *embolophora*. The second species was properly placed in synonymy to the first by Burton (1924: 206); thus *nucula* stands as genotype. This species is consistently gray in color and has a spiculation of only spherasters; these microscleres have a very large, conspicuous centrum. It is abundant throughout the West Indian region and the Mediterranean.

In and about Australia, there is another species of *Chondrilla*, characterized by a spiculation of spherasters in the ectosome and euasters in the endosome. This was first named *australiensis* by Carter (1873: 23). Since then, nine other names have been set up as supposed new species from the same region and with the same description. Burton (1924: 206 and

following) properly reduces them to synonyms. There is a species well-named *sacciformis* (Antarctic). Another (*kilakaria*) from India is like *nucula* except that it is bright orange in color. Hentschel's *jinensis* is like *australiensis*, but with huge spicules. Thus *enastra* would appear to be the sixth valid species of the genus. It is set off by its lack of spherasters—in fact it has exceedingly few spicules of any kind and thus approaches the genus *Chondrosia*, which it also resembles in color. In many other respects *Chondrosia* and *Chondrilla* are the same, the two genera being closely related.

*Xestospongia exigua* (Kirkpatrick)

This third species of sponge, collected in Yap by Dr. Hiatt, is here identified with some hesitation, and therefore is accompanied by a condensed description of the specimen. It was 20 to 30 cm. long, clavate, with contained living bivalve mollusks at intervals. It grew on tidal flats in the harbor at Yap. Only a fragment has been preserved. When dry it is very dark gray; when alive nearly black. It is hard but crumbles easily. It has a fairly even surface with oscules 2 mm. in diameter and about 2 cm. apart; the pores are very abundant and about 100  $\mu$  in diameter in the dried specimen. The spicules are packed densely around gross chambers, thus approximating a reticulate structure; they are oxeas 6 by 135 to 6 by 150  $\mu$ . A few much thinner ones are probably juvenile.

Kirkpatrick (1900: 139) described *Petrosia*

*exigua* from the East Indies and de Laubenfels (1936: 70) transferred it to *Xestospongia*. On the basis of the original rather brief description the only difference from the Yap specimen seems to be that the original had hollow ascending tracts. If it were better known, further differences might be revealed, demanding a different, perhaps new, name for the Yap species. The latter is represented by U.S.N.M. catalogue number 22733.

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## Observations on the *Haemoproteus* of Pigeons in Honolulu, Hawaii

L. KARTMAN<sup>1</sup>

DURING THE PERIOD January to July, 1948, observations were made at different times on the halteridium parasite of the pigeon, *Haemoproteus columbae* Kruse, 1890. Inasmuch as very little information has been published on the Haemosporidia of birds in Hawaii, these notes are presented with a view toward opening anew the question of blood protozoa of birds in the Territory, a problem which has never been systematically investigated. Fisher (1948) has emphasized the paucity of evidence regarding these parasites in Hawaii.

Alicata (1939, 1947) indicated that pigeons in Hawaii are commonly infected with *Haemoproteus columbae*, and Bryan (1934) showed that the hippoboscid vector, *Pseudolynchia canariensis* (Macq.), is generally distributed. No quantitative data are given in the above reports, however. The notes presented in this paper offer preliminary data on various aspects of the problem.

Pigeons and doves were examined at the Honolulu Zoo. Observations on both juvenile and adult pigeons showed them to be generally infested with the fly vector. There was an average of 2.0 flies per bird on about 50 juvenile pigeons examined and an average of 1.3 flies per bird on 100 adult pigeons. Of 45 doves examined none was found to harbor the pigeon fly, although the birds were housed in the vicinity of the pigeon lofts. This observation is in conformity with the remarks of Bequaert (1939), who indicated that *Pseudolyn-*

*chia canariensis* has never been found on a wild host in North America. On the other hand, it has been taken from at least eight species of wild Columbidae belonging to five genera in Europe, Africa, and the Philippines.

More consistent infestation was noted on juvenile pigeons which had attained full plumage. Young birds between 15 and 25 days of age had the major infestation with flies whereas younger birds were less consistently infested. Many fly puparia were found in the pigeon nests and some of these were taken to the laboratory, placed in test tubes plugged with cotton, and kept at room temperature. Flies emerged from these pupae at from 15 to 20 days after collection. Pupae observed from the time of deposition by the female fly hatched at between 23 and 37 days.

Some of the pigeon flies collected at various times were dissected for evidence of infection with the pigeon *Haemoproteus*. Table 1 summarizes the data for dissections of 25 flies taken from both young and adult pigeons. A total of 36 per cent of the flies was found to be infected; it is interesting to note that of 19 females, 36.8 per cent were infected, and of 6 males, 33.3 per cent. Although flies from several juvenile pigeons were not infected, others collected from young birds showed the infection, indicating that the fly is active in migrating from adults to young.

Blood smears were taken from birds at the zoo to determine the incidence of infection with *Haemoproteus columbae* in pigeons and to learn whether local doves are naturally infected with the pigeon parasite. Although

<sup>1</sup>Department of Parasitology, University of Hawaii Agricultural Experiment Station. Manuscript received July 30, 1948.

TABLE 1  
INFECTION OF PSEUDOLYNCHIA CANARIENSIS WITH HAEMOPROTEUS COLUMBAE IN NATURE

DATE	FLIES DISSECTED	FLIES INFECTED	NUMBER OF INFECTIONS		FLIES INFECTED	AGE OF HOST
			Midgut *	Salivary glands		
	<i>Number</i>	<i>Number</i>			<i>Per cent</i>	
3-30-48.....	12	5	5	2	41.7	juveniles and adults
3-31-48.....	4	0	0	0	0.0	juveniles only
5-12-48.....	9	4	4	2	44.4	juveniles and adults
Totals.....	25	9	9	4	36.0	

\* In addition to typical oöcysts found on the midgut, it may be of interest to note oöcysts found on the hindgut of one fly (see Fig. 3).

blood smears cannot indicate the maximum rate of infection with *Haemoproteus*, they are a rapid and accurate method of surveying for approximate incidence of infection. The smears taken from pigeons and doves were subjected to Giemsa's stain, usually within 24 hours after they were taken, and were then examined. Besides recording the positive and negative smears, in every positive smear estimates were made of the number of gametocytes infecting red blood cells. In making this estimation the actual rate of infection in 2,000 or more red cells was first tabulated and then calculated in terms of gametocytes per 10,000 red cells. The data for these

observations are shown in Table 2 and Figure 1. In addition to the data shown in the table, 38 juvenile pigeons under 30 days of age were all found negative. Two Chinese doves, *Streptopelia chinensis*, were also negative.

It is seen that the pigeons have a high rate of infection and that this rate is a little over two times the rate of infection found in the fly vector. Such an incidence in both definitive and intermediate hosts indicates an ideal situation for the life cycle of the parasite. It should be noted that most of the birds examined had mild infections. As was expected, none of the doves examined showed an infection with the pigeon parasite.

Several experiments were conducted in an attempt to transmit the *Haemoproteus* of pigeons to doves. It has been shown by Huff (1932) that the *Haemoproteus* of doves could be transmitted to domestic pigeons by the pigeon fly. However, the pigeon parasite has never been successfully transmitted to doves.

*Experiment I:* (1). On February 20, pigeon flies were collected from juvenile pigeons and 17 were placed in a cage with an infected pigeon showing 230 gametocytes per 10,000 red cells.

(2). On February 29, 10 flies were recovered from the pigeon and five were placed on a Chinese dove, *Streptopelia chinensis* (Scopoli). This dove had been captured on February 2, and blood smears taken on February 2, 15, 22, and 29 were all negative for

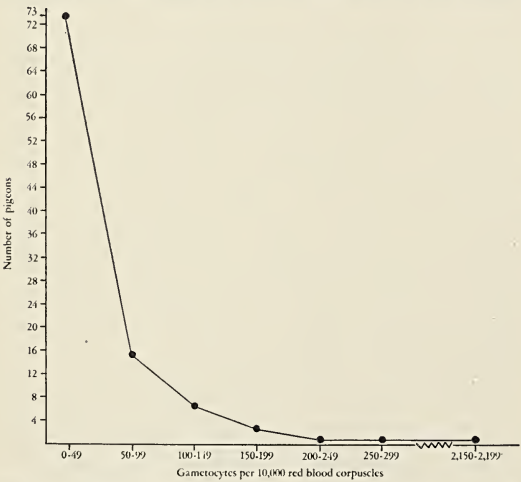


FIG. 1. Intensity of infection with *Haemoproteus columbae* in 101 pigeons (based on blood smears).



TABLE 2  
INFECTION OF PIGEONS AND DOVES WITH HAEMOPROTEUS COLUMBAE IN NATURE

DATE	BIRD	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
1-20-48.....	Pigeon	3	3	100.0
2-23-48.....	Pigeon	28	20	71.4
2-25-48.....	Pigeon	45	42	93.3
2-26-48.....	Pigeon	25	18	72.0
3-30-48.....	Dove*	43	0	0.0
Totals (Pigeons only).....		101	83	82.2

\* Thirty Indian ring-neck doves and 13 lace-neck doves.

blood parasites. The remaining five flies not placed on the dove were dissected and four were found to have oöcysts on the midgut. Salivary gland examinations were not made.

(3). Blood smears taken on March 12 and 16 were negative and on March 29 the dove was found dead in its cage. Blood smears from the heart and liver were negative for *Haemoproteus* gametocytes.

(4). Five flies were recovered from the cage containing the dead dove and dissections of these showed two with both oöcysts and sporozoites, one with oöcysts only, and two with negative midguts and salivary glands.

*Experiment II:* (1). On May 12, pigeon flies were collected from juvenile pigeons. Of three flies dissected, one was positive for sporozoites. Fifteen flies were comminuted with physiological saline in a mortar, yielding 1.5 ml. of pooled material. Approximately 0.5 ml. was injected into the pectoral muscles of one ring-neck dove, *Streptopelia decaocto* (Privalszky), one barred dove, *Geopelia striata striata* (Linn.), and one 5-week-old white Leghorn chick.

(2). Blood smears taken from these birds on June 8, 17, and July 2 were all negative and the experiment was terminated.

*Experiment III:* (1). On May 12, 10 pigeon flies were placed on an infected pigeon showing 250 gametocytes per 10,000 red cells.

(2). On May 22 the flies were removed from the pigeon and placed on a ring-neck dove. Two flies dissected were found positive for oöcysts.

(3). Blood smears taken on June 17 and July 4 were negative. Six flies taken from the dove on July 4 showed four positive for sporozoites.

All the doves were examined well within the period shown by Adie (1924) to be necessary for the appearance of gametocytes in the peripheral blood. Even in the case of the dove in Experiment I a period of 30 days intervened

between first feeding of the flies and death of the bird. Since infected flies were known to be present in these samples and since the flies feed on their host every day, it is felt that the doves had ample opportunity to become infected.

The failure to infect these doves and the chicken with the *Haemoproteus* from the pigeon substantiates the findings of Coatney (1933), who showed that the mourning dove, *Zenaidura macroura carolinensis*, is not susceptible to *Haemoproteus columbae* of the pigeon. He ascribes this to the known high degree of host specificity among many of the Haemosporidia and concludes that doves have a high degree of natural immunity toward the pigeon *Haemoproteus*.

Although earlier in this paper it was indicated that the pigeon fly was not taken on doves in nature, no difficulty was encountered in using the doves as hosts of this vector in the laboratory. Coatney (1933) also found this to be true in the case of the mourning dove.

Various workers have indicated that early stages in the sporogony of *Haemoproteus columbae* are capable of a certain amount of development in bloodsucking insects other than the hippoboscid vector. Wenyon (1926: 897) has summarized the reports of Aragão and Nöller, who indicated that oökinetes were formed in mites, bedbugs, and various species of culicine mosquitoes. In *Aedes argenteus* (= *Aedes aegypti*) Nöller found that oökinetes

formed quite readily at a temperature of 11° to 12° C. and persisted for at least 6 days.

Several experiments were conducted to test the developmental ability of the pigeon *Haemoproteus* in local mosquitoes. In all cases the mosquitoes were reared from larvae and pupae collected in the field. Adult females were fed on moist raisins for at least 2 days and were then kept from both food and water for another 2 days before their first blood meal. They were liberated into a cage 30 inches high, 28 inches wide, and 32 inches deep for feeding on infected pigeons. Feathers were plucked from about the body of the pigeons to expose the skin and to allow greater opportunity for engorgement by the mosquitoes. No difficulty was encountered in getting a sufficient number of engorged mosquitoes for the observations described below, although apparently many of the females did not feed on the pigeons. All experiments were conducted at room temperature, which fluctuated between 62.5° and 83.5° F. during this period.

*Experiment I:* (1). On February 5, starved and thirsty females of *Culex quinquefasciatus* Say were liberated into the cage containing an infected pigeon

with 250 gametocytes of *Haemoproteus columbae* per 10,000 red cells. The mosquitoes were allowed to feed overnight and engorged females were collected the next morning, placed in a small cage, and maintained on moist raisins. The engorged individuals were presumed to have had one blood meal during the night.

(2). Ten females were dissected on February 15, 10 on February 17, 5 on February 21, and 10 on March 10. All of these examinations showed midguts negative for *Haemoproteus* oöcysts.

*Experiment II:* (1). On April 30, starved and thirsty females of *C. quinquefasciatus* were liberated into a cage with a pigeon showing 175 gametocytes per 10,000 red cells. These mosquitoes were allowed to remain in the cage with the pigeon throughout the experiment and some of the engorged individuals presumably had more than one blood meal.

(2). Fifteen females were dissected on May 9, and 18 on May 16 with completely negative findings.

*Experiment III:* (1). On May 8, 10 starved and thirsty *C. quinquefasciatus* females were liberated into a cage with a pigeon showing 250 gametocytes per 10,000 red cells.

(2). On May 9, after about 18 hours, all of these females were dissected with the following results: four females showed no evidence of having taken a blood meal; six females were partially to completely engorged and stomach smears treated with Giemsa's stain showed many gametocytes of *Haemoproteus columbae* still within red cells and some exoerythrocytic rounded macrogametocytes. Some extracellular

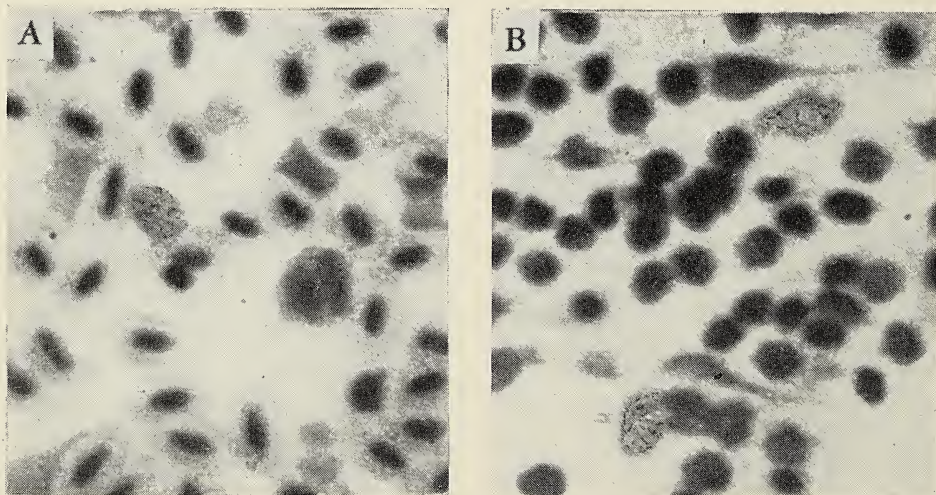


FIG. 2. Globular forms of macrogametocytes of *Haemoproteus columbae* after breaking out of red cells. (A) Smear of heparinized blood from infected pigeon. Note that one gametocyte is just breaking away from red cell. (B) Smear from midgut of *Aedes albopictus* one hour after engorging on infected pigeon. (Smears treated with Giemsa's stain. Photomicrograph by Dr. G. B. Mainland; slightly retouched.)



microgametocytes were noted, but a diligent search failed to show definite evidence of exflagellation.

All the rounded gametocytes were morphologically similar to those found in smears made from heparinized pigeon blood (see Fig. 2). No ookinetes were seen and most of the gametocytes were intracellular and typical halter forms, indicating probable immaturity.

Experiment III also included observations on *Aedes albopictus* (Skuse). Starved and thirsty females of this species were liberated into the cage on May 8 along with the other culicine described above. Two of these females were dissected 1 hour after feeding on the infected pigeon and stomach smears showed a few rounded macrogametocytes. On May 9, about 20 hours after being placed in the cage, five engorged females were dissected. Stomach smears again revealed some rounded macrogametocytes. Ten additional females were dissected on May 15 and 15 more were examined on May 23. All midguts were negative for oöcysts.

As in the case of *Culex quinquefasciatus*, the stomach smears of *A. albopictus* showed a few rounded macrogametocytes, some extracellular microgametocytes, and many halter forms still within intact red cells. No ookinetes were noted.

Experiment IV: An attempt was made to infect the hippoboscid fly (*Olfersia aenescens* Thomson), which is normally found on ocean birds. The flies used were collected by employing a juvenile red-footed booby, *Sula sula rubripes*, as a decoy. About 36 *O. aenescens* were brought to the laboratory on February 28. Ten were dissected the next day and were found negative for evidence of oöcysts on the midgut. On February 29, 20 of these flies were liberated in a cage with an infected pigeon showing 230 gametocytes of *Haemoproteus columbae* per 10,000 red cells. Most of the flies seemed attracted to the lighter side of the cage and were not apparently interested in the pigeon. Several

flies were found dead on each succeeding day and none was seen flying about the cage after 7 days. On March 10 the pigeon was removed from the cage and only one *O. aenescens* was recovered from it. Dissection of this fly showed fresh blood in the midgut, but there was no evidence of oöcyst formation.

Experiment V: Four puparia were collected from the captive *Olfersia aenescens* described above. At room temperature two of these hatched in from 52 to 53 days, but the others failed to emerge. The two flies were placed on an infected pigeon on April 24, and both immediately ran underneath the feathers. On May 4 these two flies were taken from the bird and dissected with negative findings.

#### SUMMARY

1. Observations have been made on the halteridium parasite of the pigeon, *Haemoproteus columbae* Kruse, 1890, in pigeons from lofts at the Honolulu Zoo.
2. The hippoboscid vector, *Pseudolynchia canariensis* (Macq.), was found to be present at an average rate of 2.0 per bird on about 50 juvenile pigeons and 1.3 per bird on 100 adult pigeons. Of 45 doves examined, none harbored this fly.
3. Of a total of 25 *P. canariensis* dissected, 9 or 36.0 per cent were found to be naturally infected with the pigeon *Haemoproteus*.
4. Of 101 adult pigeons examined by the blood smear technique, 83 or 82.2 per cent were positive for *Haemoproteus columbae*. Of 43 doves examined, none was found infected with the pigeon parasite or any other blood protozoan.

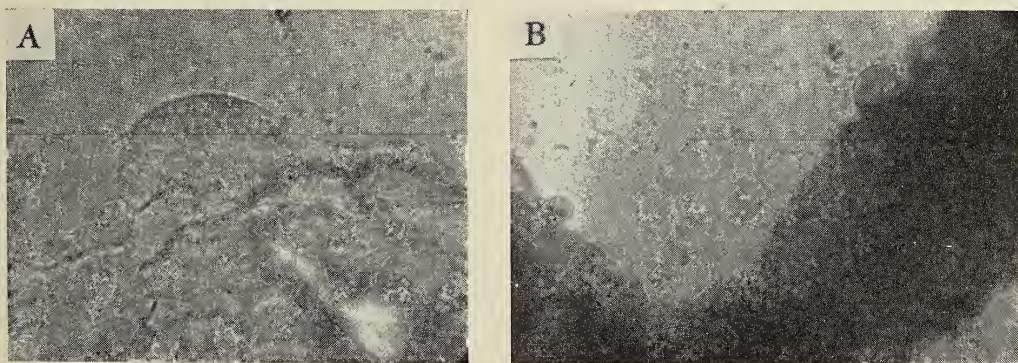


FIG. 3. Left: Oöcyst of *Haemoproteus columbae* on midgut of *Pseudolynchia canariensis*. Approx. 950X. Right: Oöcysts of *H. columbae* on hindgut of *P. canariensis*. Approx. 440X.

5. Attempts to transmit the pigeon *Haemoproteus* to three species of doves and to a young chicken, either by means of the fly vector or by inoculation of macerated flies, proved negative.
6. Oökinetes and oöcysts failed to develop in *Culex quinquefasciatus* Say, *Aedes albopictus* (Skuse), and *Olfersia aenescens* Thomson when these species were allowed to feed on infected pigeons. *O. aenescens* did not feed readily on pigeons. Smears of the stomach contents of engorged female mosquitoes of both species showed mainly halter forms in red cells and some rounded macrogametocytes. Some extracellular microgametocytes were also noted but definite evidence of exflagellation was not found.

*Acknowledgments:* Thanks are due the following persons for their aid in these experiments: Paul Breese, Director of the Honolulu Zoo, for generously allowing complete freedom in observations and examinations of pigeons and other birds; Jane Y. C. Yuen for her aid in taking blood smears and for laboratory help; Dr. D. D. Bonnet, Territorial Board of Health, for supplies of larval and pupal *Culex quinquefasciatus*; Dr. Frank Richardson, Assistant Professor of Zoology, University of Hawaii, for help in collecting hippoboscids from ocean

birds; and Dr. J. Bequaert, Harvard Museum of Comparative Zoology, for identifying the *Olfersia aenescens*. Appreciation is also due the University of Hawaii Agricultural Experiment Station for the use of certain of its facilities.

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# A Revision of the Genus *Alstonia* (Apocynaceae)<sup>1</sup>

JOSEPH MONACHINO

## INTRODUCTION

THE GENUS *Alstonia* was proposed in a paper by Robert Brown read before the Wernerian Natural History Society in 1809 and published in 1811. It was named in honor of Charles Alston, Scottish physician and professor of botany at the University of Edinburgh. Four species were referred to this genus by Brown, namely, *A. scholaris*, *A. venenata*, *A. costata*, and *A. spectabilis*. Each of these is the type species of a section of *Alstonia*; therefore all the sections recognized in the present treatment, except § *Winchia*, were represented at that early date. To that great naturalist is to be given not only the credit for erecting the foundations for the genus, but also for having a marvelous perspicacity in recognizing a generic tie between such diverse elements as those known to him.

Five sections of *Alstonia*, 39 species, and 12 varieties are treated in the systematic section of the present paper. The scope and problems in the treatment are discussed before the taxonomy is elaborated.

The type of the genus is *A. scholaris*, and this species is in many respects the most important one in *Alstonia*. The specific epithet was derived from *lignum scholare*, a name applied to the plant because of the use of its wood for making writing tablets employed in schools. Reference to this was made in 1741 by Rumphius, who also noted other uses for the species.

The bark of *A. scholaris* has been reported to be the source of one of the most widely known and important of the popular drugs in the Philippines, and the product is very highly esteemed in the popular medicine of India, where it has found a place as a standard drug in the pharmacopoeia. It has been credited with the properties of being an astringent tonic, anthelmintic, alterative, antiperiodic, etc., useful in various febrile conditions as well as in chronic diarrhea and dysentery. A poultice made from the leaves of *A. scholaris* has been reported as used for skin disease in India, and the sap of some Fijian species as used by the natives for eye trouble. Examples of reports of various additional uses of *Alstonia* species follow: the Bakweli administer latex of *A. Boonei* to women to increase lactation and enrich their milk while suckling young; latex of *A. angustiloba* is used with copper sulfate for yaws, and that of *A. scholaris* is mixed with oil and used to treat earache; the leaf, root, and bark of *A. congesta* [or *A. Boonei*] are used externally in treating rheumatic pains.

In more modern times, the bark of *A. scholaris* has been regarded as a remedy of considerable promise in debility after fevers and other exhausting diseases. Rakshit (1944) wrote that the total alkaloids obtained by his method of extraction possessed definite anti-malarial constituents. This investigator suggested that the negative tests obtained by others were the result of inadequate methods of extraction which did not dissolve out the proper alkaloids.

<sup>1</sup> This study is made possible by the financial support of the Chicle Development Company. Manuscript received November 15, 1947.

The use of *Alstonia* as an antiplasmodial is frowned upon, but the antipyretic effectiveness of *A. scholaris* has apparently been substantiated by recent findings such as those of B. Mukerji (1946), who states that he has observed febrifugal action of a pronounced degree.

Many alkaloids have been isolated from *Alstonia* bark. Henry (1939) lists 11 species as having been examined for alkaloids, all with positive findings. Not one of the species listed belongs in the § *Blaberopus*, or the § *Winchia*. The latter, with its single species, is closely related to § *Pala*, but § *Blaberopus* is highly distinctive and certainly merits careful investigation. In the § *Dissuraspermum* only *A. constricta* was examined, a species hardly typical of the section. Henry lists *A. somersetensis* and *A. spectabilis*. The identity of these species is not clear. The former might be either *A. spectabilis* or *A. Muellieriana*, the latter, *A. scholaris*.

While *Alstonia* alkaloids occupy an important place in chemical literature, much less is known about the value of the latices. The widely distributed *A. scholaris*, the very closely related African representatives, and also other species are immense trees bearing copious latex of good quality for use as chewing gum. The latex of *A. angustiloba* is reported to have been analyzed and found similar to that of *Dyera* (Anonymous, 1910) and it has been noted that the latex of *A. angustifolia* solidifies to something like jelutong. Marx Lang (1925: 11) states that *A. Vieillardii* "pourrait devenir facilement l'objet d'une culture intéressante, car il a donné, a la saignée, les 7/10 des son volume en caoutchouc." The latex obtained from the branchlets and petioles of *A. vitiensis* and related species is used by the Fijians as a source of chewing gum. A sample of caoutchouc prepared from a Fijian *Alstonia* was sent to England and the quality was highly valued (Morris, 1898: 48).

The wood of *A. spatulata* is among the lightest known. The timber of *A. scholaris* is used

in a minor way for boxes, furniture, and like articles. The wood of *A. scholaris* is not durable and that of *A. Boonei* is subject to insect attack and decay; they possibly are suitable for paper pulp.

The potential commercial possibilities of *Alstonia* pose the question of availability of large quantities of plant material. The natural range of *Alstonia* is an immense, almost continuous belt in the palaeotropics, stretching from the west coast of Africa to the Marquesas in the far eastern Pacific, and from the Himalayas to New South Wales. Species grow at altitudes and under conditions varying from sea level to very great heights, in deep swamps and rain forests to rather dry ground and areas of moderate rainfall, in soils of rich humus to clay or limestone. Although *Alstonia* species apparently do not form exclusive stands in virgin forests, great numbers of individuals are sometimes found in certain localities. In distributional character, therefore, *Alstonia* has an advantage over its sister genus, *Dyera*, the well-known producer of jelutong; also in the diversity of its taxonomic elements, embracing 5 sections, 39 species, 12 varieties, and countless forms, *Alstonia* enjoys an advantage over *Dyera*, which comprises merely two closely related species (Monachino, 1946: 189).

Continuing on the subject of availability, what promise has *Alstonia* as a cultivated crop? Several attempts have been made in the cultivation of *Dyera*, but without conclusive results (Monachino, 1946: 178-180). No extensive experiment has been reported on the cultivation of *Alstonia*, but *A. scholaris*, as an ornamental, has proved quite adaptable in climates such as southern Florida and California in the United States, Puerto Rico and Dominica in the West Indies, Calcutta in India, and Buitenzorg in Java. Duss (1897: 397) noted that *A. scholaris* grown in the botanic garden at Saint-Pierre, Guadeloupe, covered itself with flowers in October or November but did not produce fruits.



*Literature:* No work of monographic character on the genus *Alstonia* has hitherto been attempted. Taxonomic treatments have been of a local nature and are found principally in regional or general floras. An example of such treatments is Hooker's flora of British India (1882: 630, 641–643). The species of the Malay Peninsula are presented in excellent style in King and Gamble's flora of the Malay Peninsula (1907). Four of these species are also described by Pitard in Le Comte's *Flore Générale de l'Indo-Chine* (1933: 1161–1166). Comments on certain species from China appear in Tsiang's *Notes on the Asiatic Apocynales* (1934, 1936). Koorders and Valeton's *Bijdrage No. 1 tot de Kennis der Boomsoorten van Java* (1894: 115–125) and Miquel's *Flora Indiae Batavae* (1856: 436–440) refer to species of *Alstonia* in Java. The species found in New Guinea are interpreted by Markgraf (1927). Bentham's *Flora Australiensis* (1869: 312–315) deals with the Australian representatives of *Alstonia*. There is no single taxonomic treatment of all the species known from New Caledonia, but 11 are cited by Spencer Moore (1921: 362–364) of which five are described as new. Guillaumin (1911a: 195–196) cites 13 species and Schlechter (1906: 235–237) cites seven species. The account of *Alstonia* in Samoa given by Christophersen (1935: 177–180) and other reports, by various authors, on the genus in the Pacific islands or in Africa are of importance only for individual species.

Of works other than taxonomic, J. K. Santos' *Histological Study of the Bark of Alstonia scholaris* R. Brown from the Philippines is of particular interest. H. H. Janssonius (1926: 610–626) treats the wood anatomy of *A. scholaris*, *A. spectabilis*, *A. angustiloba*, and *A. spatulata* and presents a key to these species based on wood structure (1925: 576). The lightweight wood of *A. spatulata* is discussed by E. Graffe (1934).

Chemical and physiological studies of extracts of *A. scholaris* are presented by R. F. Bacon (1906: 1008–1019). Here references

are made to earlier workers who have investigated *Alstonia* for its therapeutic and chemical properties. Noteworthy among these are Jobst and Hesse, Gorup-Besanez, Gruppe, and Harnack. The first four of these authors are cited by Santos, who, in addition, cites Dymock and Flückiger and Hambury.

Recently, Pichon (1947) wrote a very interesting paper on *Alstonia*. His article is discussed in the Supplement following the body of the present treatise. Pichon suggested that the Central American–Mexican *Tonduzia* is truly an *Alstonia*. The seeds of *Tonduzia*, however, are not ciliate as in *Alstonia* but finely membranously lacerate along the margins.

*System of arrangement of material:* In the taxonomic portion of this paper, the key to the sections, diagnoses of the sections, and the keys to all the species and varieties immediately follow the description and discussion of the genus. Secondary sectional characters are given in the body of the paper preceding the treatment of the individual species belonging to the section. For full characterization of each species it is necessary to read the individual description, and also the secondary sectional generalizations heading the group, as well as the original diagnosis of the section.

In the treatment of the species reference is made only to those illustrations which were available and, in the writer's opinion, significant; a complete survey of illustrations or of the bibliography was not attempted. Not all specimens examined in the well-represented species are cited.

In order to save space, the citation of herbaria is generally limited in the following fashion: If the specimen is deposited at the New York Botanical Garden no indication is made of herbaria where it is deposited. If the collection is not represented here but is represented at the Arnold Arboretum, then that institution is cited exclusively. If not in either the Arnold Arboretum or the New York Botanical Garden but present in the Gray Herbarium the latter only is cited. If not in any

of the above three herbaria, then complete citation is made; also complete references to herbaria are given in special cases.

*Abbreviation of herbaria:* The depositories of the specimens examined are abbreviated as proposed in *Chronica Botanica* (Lanjouw, 1939), where complete names and addresses of the herbaria are given, arranged in alphabetic sequence according to city in which they are located. The following abbreviations appear in this paper: A (Jamaica Plain), Bish (Honolulu), BM (London), Br (Bruxelles), Bri (Brisbane), Cal (Calcutta), F (Chicago), Fi (Firenze), G (Genève), GH (Cambridge), K (Kew), L (Leiden), Min (Minneapolis), Mo (St. Louis), NY (New York), P (Paris), Sing (Singapore), UC (Berkeley), US (Washington).

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#### DISCUSSION

Two new sections of the genus *Alstonia* are proposed in the present paper. One is based on the genus *Winchia* and consists, at present, of but a single species, including in its synonymy *A. pachycarpa* and *A. rostrata*. The section *Winchia* has syncarpous ovaries and connate follicles, features not previously recognized in *Alstonia*. The other new section embraces species which have hitherto been incorporated in § *Dissuraspermum*. Seed morphology is stressed as being of sectional importance.

It is not surprising that only one new species (*Alstonia Brassii*) is described, for in a genus consisting of conspicuous, greatly polymorphic species superfluous names are usually freely published until a comprehensive treatment is rendered.

Study has forced a disposition of the well-known *A. villosa* in synonymy under the neglected but prior *A. spectabilis*. *A. congensis* is identified with *A. Gilletii*; consequently the greater part of the material hitherto distributed as *A. congensis* is now referred to *A. Boonei*. *Blaberopus Sebusi*, long since buried and forgotten as merely a mixture of *A. venenata* and *A. neriifolia*, is resurrected as a legitimate species of *Alstonia*, with the description of a variety adduced as supporting evidence of its integrity. *A. Muelleriana* is reinstated. Several other novel interpretations, sometimes radically divergent from those currently accepted, have been necessary.

Eight new varieties<sup>2</sup> are introduced in the present work. This is partly a reflection of the polymorphic nature of *Alstonia*; these varieties often serve as convenient intermediates between species that are clearly distinct only in their typical forms.

I am not completely satisfied with my treatment of several problems in *Alstonia*. No authenticated specimens of *A. spectabilis*, which is one of the three basic species founded at the same time as the genus, were available. It is here designated as type of a new section and interpreted as widespread in the Malay Archipelago. Neither types nor authenticated material of *A. glabriflora* and *A. Kurzii* were seen.

In § *Blaberopus*, I have a somewhat uneasy feeling concerning the great distributional gap shown by *A. neriifolia*, which is known from sub-Himalayan India and apparently appears also in Java.

Most disturbing are several cardinal problems still unsolved concerning the species of *Alstonia* in the Pacific. *A. plumosa* was not identified; this, being the second *Alstonia* described from the area, has involved species both in New Caledonia and in the more eastern Pacific islands. No specimen of *A. Godeffroyi* was identified, and one may wonder whether the

<sup>2</sup>No use is made of trinomials with the formal designation "var. *typica*," etc., for the nomenclaturally typical element.



later *A. Reineckean*a is not truly synonymous with this. Aside from the nomenclatural difficulties, there is suspicion of the criteria employed by me for taxonomic evaluation of morphological characters observed in the baffling *plumosa*–*costata* species complex. Only photographs of *A. Comptonii* and *A. saligna* were examined. The fruits of *A. quaternata* were not available, and since the plant is unique in several features there is uncertainty about its sectional, and possibly its generic, status.

### Genus *ALSTONIA* Brown

*Alstonia* R. Br., in Mem. Wern. Soc. 1: 75. 1811 (nom. conserv.). Non Scop., Introd. Hist. Nat. 198. 1777; non Mutis ex L. f., Suppl. 39. 1781.

*Pala* Adr. Juss., in Ann. Mus. Paris 15: 346. 1810.

*Blaberopus* A. DC., Prod. 8: 410. 1844.

*Winchia* A. DC., Prod. 8: 326. 1844.

*Amblyocalyx* Benth., in Benth. and Hook., Gen. Pl. 2: 698. 1876.

*Paladelph*a Pichon, in Paris Mus. d'Hist. Nat., Bul. II, 19: 299. 1947.

Laticiferous trees or shrubs. Leaves verticillate or opposite, penninerved, the lateral nerves (principal secondaries) varying from very numerous and close to few and distant, 1–30 mm. apart (the average distance apart near middle of blade). Calyx without glands, the tube very short, the lobes 5; inflorescences apparently terminal, the primary peduncles usually several, more or less branched, the flowers cymose, white to yellow or red; corolla tube cylindric, slightly inflated at region of anthers, thickened at throat, pubescent within below stamens and more sparsely so or glabrous above, or densely barbate at throat in § *Blaberopus*; corolla lobes spreading at maturity, more or less barbate at base within; anthers on short but distinct filaments, dehiscent their entire lengths or only for the greater part (spp. in § *Pala*), without appendages; ovary apocarpous or syn-

carpous in § *Winchia* (? *A. quaternata*), superior or partly inferior, ovules numerous, in many ranks or rarely in two or three ranks in each cell; style long and filiform to very short, glabrous; stigma reaching up to anthers, the stigma-apiculi short, papillose, the clavuncle cylindric, often variably penicillate above, membranous indusiate above and tunicate below; follicles separate or united into a single capsule (§ *Winchia*), rather slender, lightly striate outside. Seeds numerous, very light, thin and flattened, ciliate, the surface minutely foveolate, the placental scar at about middle, the embryo about length of seed-body, the cotyledons about length of radicle, broadly elliptic to narrowly oblong or linear.

Type species.—*A. scholaris* (L.) R. Br.

*Alstonia* R. Br. versus the two earlier homonyms by Mutis ex L. f. and Scopoli was proposed for conservation by Rehder (1935: 352) and conserved by the 6th International Botanical Congress, Amsterdam (1935).

*Alstonia* Scop. was based on *Pacouria* Aubl., a name now rejected in favor of *Landolphia* Beauv.

*Alstonia* Mutis ex L. f. is typified by *A. theaeformis*. The species was transferred to *Symplocos* by Gürke, and this disposition is accepted by Brand (1901: 81) in his monograph of the Symplocaceae.

*Pala*, rejected in favor of *Alstonia*, was based on "Pala" Rheede (1678: 81, t. 45), which is *A. scholaris*. It was published without a specific name and has never been adopted as a genus by any other author. The citation was followed by a very brief description but the identity of *Pala* with *Alstonia* is unquestionable. There is some doubt, however, whether Jussieu intended formally to propose *Pala* as a genus or wished merely to note that the plant designated as "Pala" by Rheede in 1678 should merit generic distinction.

Of the five sections in *Alstonia*, *Blaberopus* has most to recommend it for recognition as a distinct genus but is here considered fairly well within the generic latitude of *Alstonia*. A. Gray

implied that his subgenus *Dissuraspermum* might be wholly detached from *Alstonia* with better reason than *Blaberopus* had been.

The character of syncarpous ovary and united follicles found in *Winchia* are in themselves not of sufficient importance to maintain a distinct genus. There is experience in another genus of Apocynaceae, *Wrightia*, in which the character of connate follicles in certain species is of minor significance and cannot serve to segregate them generically from other species having widely divergent follicles. The close relationship between § *Winchia* and § *Pala* is very marked.

*Amblyocalyx* owes its origin to an erroneous observation of the ovary of a specimen of *A. angustifolia*, in which the ovule masses were mistaken for single ovules. It was originally published without a specific name: "Species I (v. 2?) Borneensis, Beccari 1628 et 3207." Subsequently it was typified by 1628, *Amblyocalyx* Beccarii.

The genus *Alstonia* is amply distinct, its only close relative being *Dyera*. The § *Pala* is closest to *Dyera*. Besides its habit and vegetative similarity, the dehiscence of the anthers in some of the species in this section indicates affinity.

The form of ciliation in the seeds of *Alstonia* is almost unique in the Apocynaceae. A similar ciliation is found in *Laxoplumeria*, a South American genus of trees having alternate leaves. The seeds of *Alstonia* are invested with cilia at both ends, the distinct hairs being in some species sparsely distributed and in others rather densely set, but at no time truly comose as in *Holorrhena* and *Wrightia*, for example, or in other apocynaceous genera.

There is no easy way of distinguishing *Alstonia* from some other genera. *Rauvolfia*, *Tabernaemontana*, and *Ochrosia* have been frequently confused with *Alstonia*. With the examination of the seeds no such confusion could be possible. If the plant is a tree or shrub with verticillate or opposite leaves, and its seeds are ciliate, it is an *Alstonia*. Given seeds, not only the genus but also the section can almost always be determined; without seeds, the assigning of

an unfamiliar species to *Alstonia* would be a very difficult task.

The distribution of native species of *Alstonia* in the major land groups of its range is as follows:

Africa—*Boonei*, *congensis*

India—*neriifolia*, *scholaris*, *Sebusi*, *venenata*

Burma to China—*angustifolia*, *glaucescens*, *macrophylla*, *Mairei*, *scholaris*, *Sebusi*, *spatulata*, *venenata*, *yunnanensis*

Malayan Peninsula and Archipelago (Malaysia)

—*angustifolia*, *angustiloba*, *Curtisii*, *glaucescens*, *macrophylla*, *neriifolia*, *parvifolia* (Borneo ?), *pneumatophora*, *rupestris*, *scholaris*, *spatulata*, *spectabilis*

Philippines—*angustiloba*, *macrophylla*, *parvifolia*, *scholaris*, *spectabilis*

New Guinea—*actinophylla*, *Brassii*, *glabriflora*, *Muelleriana*, *scholaris*, *spectabilis*

Australia — *actinophylla*, *constricta*, *linearis*, *Muelleriana*, *ophioxylodes*, *scholaris*, *spectabilis*

Melanesia (excluding New Caledonia)—*scholaris*, *spectabilis*, *vitiensis*

New Caledonia—*Comptonii*, *Deplanchei*, *lanceolata*, *Legouixiae*, *Lenormandi*, *plumosa*, *quaternata*, *Roeperi*, *saligna*, *Vieillardii*

Fiji and eastern Pacific islands—*costata*, *Godefroyi*, *montana*, *Reineckeana*, *vitiensis*

#### Key to the Sections of *Alstonia*

1. Corolla lobes with left margins overlapping; seeds not acuminate or caudate; stamens inserted manifestly above middle of corolla tube, located at or near throat; leaves 3- to 11-verticillate, lateral nerves close and numerous ..... 2
- Corolla lobes with right margins overlapping; seeds acuminate or acute at one or both ends..... 4
- 2(1). Disc annular or not apparent, not lobed; seeds with thick rounded margins at ends; leaves rounded to acuminate but not finely pointed at apex; large trees ..... 3
- Disc with two conspicuous deltoid to linear lobes; seeds with thin, often



erose margins at ends; leaves finely pointed at the acuminate apex; small shrubs; anthers over 1.4 mm. long

..... *Blaberopus*  
3(2). Follicles connate into a single thick capsule ..... *Winchia*

Follicles divergent, slender..... *Pala*

4(1). Seeds rounded to subacute at one end and acute to caudate at the other, densely ciliate at ends with long coma-like hairs; leaves 3- to 4-verticillate, lateral nerves distant, reticulation manifest ..... *Monuraspermum*

Seeds manifestly narrowed-acute to long slender caudate at both ends, cilia short, not coma-like; leaves opposite, or rarely both opposite and 3-verticillate ..... *Dissuraspermum*

Section WINCHIA (A. DC.) Monachino, stat. nov.

*Winchia* A. DC., Prod. 8: 326. 1844.

Like § *Pala* but ovary syncarpous and follicles united into a single thick capsule; leaves less pale beneath than in § *Pala*. Known at present from a single species. Trees; leaves 3- to 4-verticillate, green on both sides or slightly paler beneath, the lateral nerves numerous, close, parallel, straight or slightly arcuate, horizontal or a little ascending; corolla lobes with left margins overlapping; anthers located at throat of corolla, the filaments attached manifestly above middle of corolla tube; ovary syncarpous, disc not conspicuous; follicles united into a single thick capsule; seeds oblong, rounded at both ends, margins thick, glabrous on faces, long-ciliate at ends; placental scars linear.

Type species.—*A. glaucescens* (K. Schum.) Monachino.

Section PALA (Adr. Juss.) Benth., in Benth. and Hook., Gen. Pl. 2: 705. 1876.

*Pala* Adr. Juss., in Ann. Mus. Paris 15: 346. 1810.

Subgen. *Pala* King & Gamble, in Jour. As. Soc. Beng. 74(2): 435. 1907 (*in clavis*).

Series *Glabrae* Pichon, in Paris Mus. d'Hist. Nat. Bul. II, 19: 296. 1947.

Series *Pilosae* Pichon, in Paris Mus. d'Hist. Nat. Bul. II, 19: 296. 1947.

Trees. Leaves 3- to 11-verticillate, undersides pale to strongly cinereous, habitually with microscopic papillae, the lateral nerves numerous, close, parallel, straight or slightly arcuate, horizontal or a little ascending. Corolla lobes with left margins overlapping; anthers located at throat of corolla, the filaments attached manifestly above middle of corolla tube; ovary apocarpous, disc not conspicuous. Seeds oblong, rounded at both ends, margins thick, glabrous on faces, long-ciliate at ends; placental scar linear.

Type species.—In proposing this section, Bentham (1876) cited the genus *Pala* in synonymy and referred to the illustrations Wight Ic. t. 422 and Bedd. Fl. Sylv. t. 242. These illustrations are of *A. scholaris*, and the Jussien *Pala* was also based on the same species. The type of section *Pala* is therefore *A. scholaris* (L.) R. Br.

#### Key to Section *Pala*

1. Corolla pubescent outside; leaves generally broadest above middle, the transverse veins and reticulation prominulous on upper surface..... 2
- Corolla glabrous outside..... 5
- 2(1). Inflorescence with flowers in very closely crowded cymes, pedicels up to 3 mm. long; calyx densely tomentose outside; corolla lobes quadrate-orbicular, 2.0 to 4.5 mm. long and as broad. Plants not of Africa..... 3
- Inflorescence with flowers more loosely disposed; pedicels to 6 or 8 mm. long. Africa ..... 4
- 3(2). Leaves glabrous..2. *A. scholaris* (typical)
- Leaves softly villose on underside.....
- .....2a. *A. scholaris* var. *velutina*
- 4(2). Calyx densely tomentose outside; ovary densely pubescent; typical corolla tube 6 to 12 mm. long, corolla lobes 3 to 6 mm. long, about as broad as long; follicles tomentose; leaves petioled, petioles 1 to 2 cm. long.....
- .....3. *A. Boonei*
- Calyx glabrous or sparsely pubescent outside; ovary glabrous or nearly so; typical corolla tube 4 to 6 mm. long, corolla lobes 5 to 9 mm. long, much longer than broad; follicles glabrous; leaves sessile or almost so, petioles less than 0.5 cm. long....4. *A. congensis*

- 5(1). Leaf blades markedly spatulate, rounded at apex, principal lateral nerves 20 to 35 pairs. Malaya..... 6  
 Leaf blades elliptic, narrowed or acuminate at apex..... 8
- 6(5). Inflorescence loosely cymose, sparsely flowered, glabrous; pedicels long, up to 13 mm. long; corolla lobes large, 7 to 12 mm. long, 4 to 5 mm. broad; follicles glabrous..... 7. *A. spatulata*  
 Inflorescence with numerous flowers very closely crowded, puberulent; pedicels very short, up to 3 mm. long; corolla lobes 3 to 5 mm. long, about 2 mm. broad, follicles puberulent..... 7
- 7(6). Petioles 0 to 0.7 cm. long.....  
 ..... 6. *A. pneumatophora* (typical)  
 Petioles about 2 cm. long.....  
 ..... 6a. *A. pneumatophora* var. *petiolata*
- 8(5). Inflorescence in rather closely flowered cymes, puberulent; calyx lobes puberulent outside; leaf blades 3 to 7 cm. broad, principal lateral nerves 40 to 100 pairs. Malaya..... 5. *A. angustiloba*  
 Inflorescence in loose cymes, glabrous; calyx lobes glabrous outside; leaf blades narrow, 1 to 3 cm. broad, principal lateral nerves 35 to 50 pairs. Australia-New Guinea.....  
 ..... 8. *A. actinophylla*

Section BLABEROPUS (A. DC.) Benth., in Benth. and Hook., Gen. Pl. 2: 705. 1876.  
*Blaberopus* A. DC., Prod. 8: 410. 1844.  
 Subgen. *Blaberopus* King and Gamble, in Jour. As. Soc. Beng. 74(2): 435. 1907 (*in clavis*).

Shrubs, sometimes dwarf; leaves 3- to 6-ver-ticillate, acuminate and finely pointed at apex, not markedly pale beneath, not microscopically papillose, the lateral nerves numerous, close, finely raised-striate on upper surface, lightly arcuate, joined by a fine marginal nerve, the transverse veins hardly showing; corolla tube densely bearded with moniliform hairs at throat; corolla lobes with left margins overlapping; anthers located at throat of corolla (below the throat in *A. Curtisii*), comparatively large (over 1.4 mm. long), the pollen grains much larger than in other sections (about twice as large or 45–60 $\mu$ ), the filaments attached manifestly above middle of corolla tube; ovary apocarpous,

the disc manifest, with two conspicuous lobes opposite sutures of ovary; seeds a little narrowed but not acuminate at ends, long-ciliate at ends and often truncate-erose, faintly membranous-margined particularly at ends, sparsely pubescent on faces; placental scar short.

Type species.—In proposing this section Bentham (1876) cited the genus *Blaberopus* A. DC. in synonymy and referred to the illustrations Wight Ic. t. 436 and Lodd. Bot. Cab. t. 1180. These illustrations are of *A. venenata*, which is the earliest species representing *Blaberopus*. The type of § *Blaberopus* is therefore *A. venenata* R. Br.

#### Key to Section *Blaberopus*

1. Calyx lobes ciliate..... 2  
 Calyx lobes not ciliate, not acuminate; follicles not stipitate; leaves 5 to 12 cm. long, glabrous..... 8
- 2(1). Calyx lobes greatly attenuate and finely acute at apex; leaves sessile or almost so, hispidulous beneath or at least scabridulous on midrib; corolla lobes 3 to 6 mm. long, ciliate; corolla tube about 1 cm. long; follicles not stipitate..... 15. *A. yunnanensis*  
 Calyx lobes not acuminate; leaves manifestly petioled; corolla lobes not ciliate..... 3
- 3(2). Follicles with slender stipes (stipes 1.5 to 3.0 cm. long), somewhat fusiform, 6 to 13 cm. long, 6 to 7 mm. diameter..... 4  
 Follicles not stipitate, slender cylindric, 10 to 14 cm. long, 3 to 4 mm. diameter; corolla lobes 6 to 18 mm. long..... 7
- 4(3). Corolla lobes short, 2 to 3 mm. long; corolla tube about 1 cm. long; stigma-apiculi long and sharp..... 5  
 Corolla lobes long, 12 to 20 mm. long; corolla tube 2 to 3 cm. long; stigma-apiculi short and blunt..... 6
- 5(4). Leaves beneath and inflorescence pubescent with short spreading hairs. Himalaya..... 11. *A. Sebusi* (typical)  
 Leaves and inflorescence glabrous. Yunnan..... 11a. *A. Sebusi* var. *szemaoensis*
- 6(4). Leaves and inflorescence glabrous.....  
 ..... 9. *A. venenata* (typical)  
 Leaves beneath and inflorescence pubescent with short spreading hairs.....  
 ..... 9a. *A. venenata* var. *pubescens*



- 7(3). Leaves sericeous-pubescent beneath.....  
.....10. *A. neriifolia* (typical)  
Leaves glabrous .....  
.....10a. *A. neriifolia* var. *glabra*  
8(1). Corolla lobes long, about 9 mm. long,  
corolla tube about 2 cm. or more  
long; perioles about 1 cm. long; lobes  
of gland much narrower than ovary;  
anthers over 2 mm. long..... 9  
Corolla lobes short, about 2.5 mm. long,  
corolla tube about 1 cm. long; leaves  
sessile; lobes of gland almost as broad  
and long as ovary; anthers about 1.5  
mm. long.....14. *A. rupestris*  
9(8). Corolla tube inflated at throat, about 2  
cm. long; anthers located at throat,  
their apices almost reaching bases of  
corolla lobes.....12. *A. Mairei*  
Corolla tube conspicuously constricted  
at throat for a length of about 5 to 6  
mm. below mouth, inflated at about  
1/4 of its distance from mouth, about  
2.5 to 3 cm. long; anthers located  
below throat, their apices being about  
6 mm. from corolla lobes.....  
.....13. *A. Curtisii*

Section MONURASPERMUM Monachino, sect.  
nov.

Sect. *Dissuraspermum* Benth., ser. *Occiden-  
tales* Pichon, in Paris Mus. d'Hist. Nat. Bul.  
II, 19: 297. 1947 (pro part.).

Arbores foliis 3- vel 4-verticillatis; venis  
secundariis foliorum distantibus arcuatis; lobis  
corollae marginibus dextris imbricatis; disco  
annulare et angusto vel obscuro; seminibus ad  
cacumen aliud rotundatis usque ad subacutis,  
ad cacumen aliud acutis usque ad acuminatis,  
cacuminibus comoso-ciliatis.

Trees. Leaves 3- or 4-verticillate, not micro-  
scopically papillose beneath, the principal lateral  
nerves distant, arcuate near margin and con-  
nected by a faint looping marginal nerve, the  
anastomosing veins and close reticulation mani-  
fest; corolla lobes with right margin overlap-  
ping; disc annular, very narrow or not apparent;  
follicles separate; seeds elliptic, rounded to  
obtuse or sometimes subacute at one end, acute  
to acuminate or caudate at the other, tails not  
forked, faces densely pubescent, ends long-ciliate  
with coma-like hairs, sides short-ciliate to gla-  
brous; placental scar short.

Type species of the section.—*A. spectabilis*  
R. Br.

Schumann, in Engler and Prantl (1895: 139),  
included species belonging in the present sec-  
tion under § *Dissuraspermum*; King and Gam-  
ble (1907: 435), in key, did likewise under  
the subgenus *Dissuraspermum*. The two sections  
are without doubt closely related.

Key to Section *Monuraspermum*

1. Leaves narrowly linear, about 7 cm.  
long and only 1.5 to 3 mm. broad,  
the lateral nerves about 40 pairs,  
1 mm. apart.....24. *A. linearis*  
Leaves not linear, more than 2 cm.  
broad, the lateral nerves less than  
30 pairs, more than 2 mm. apart.... 2  
2(1). Calyx densely gray or rusty-tomentose  
outside; pedicels not long and  
slender; corolla lobes not ciliate or  
hardly so; corolla tube mostly to-  
mentose outside ..... 3  
Calyx puberulent to glabrous, not  
tomentose outside; corolla tube  
glabrous outside; corolla lobes  
mostly ciliate ..... 9  
3(2). Lobes of calyx densely pubescent in-  
side as well as outside, their mar-  
gins thick; stamens inserted near  
middle of corolla tubes..... 4  
Lobes of calyx glabrous inside or  
sparsely pubescent near apex, their  
margins thin; stamens inserted  
near throat of corolla tube; corolla  
lobes broadly rounded or ovate,  
densely pubescent outside and in-  
side; inflorescent branches and  
pedicels ascending ..... 8  
4(3). Calyx urceolate, the lobes broadly  
ovate, mostly reflexed; inflorescent  
branches and pedicels divaricate.... 5  
Calyx turbinate, the lobes ovate to  
lanceolate, not reflexed; inflores-  
cent branches and pedicels as-  
cending; corolla densely pubescent  
outside, corolla lobes linear- or  
oblong-lanceolate, about 3 or 4  
times as long as broad. Australia  
and Papua.....20. *A. Muelleriana*  
5(4). Corolla lobes broadly rounded, less  
than 3 mm. long and about as

- broad, densely pubescent outside and inside; calyx about 2 mm. or less long; corolla tube densely tomentose outside. Malaya..... 6
- Corolla lobes oblong, about 3 mm. or more long and about half as broad, glabrous or slightly puberulent outside and sparsely pubescent inside; calyx over 2 mm. long; corolla tube mostly glabrous or sparsely pubescent outside. Philippines and Borneo....17. *A. parvifolia*
- 6(5). Petioles mostly 1 to 2 cm. long, blades 2 to 6 cm. broad; calyx lobes mostly spreading; corolla tube 2.3 to 3.5 mm. long; anthers 0.6 to 1 mm. long..... 7
- Petioles 2.5 cm. long, blades 6.5 to 8 cm. broad; calyx lobes hardly spreading, sharper at apex than in the typical form; corolla tube 4.5 to 5.5 mm. long; anthers 1 to 1.3 mm. long.....
- .....16b. *A. angustifolia* var. *latifolia*
- 7(6). Corolla tube 3 to 3.5 mm. long, corolla lobes broadly oblong-ovate; calyx tube about 1.2 to 1.3 mm. long.....16. *A. angustifolia* (typical)
- Corolla tube 2.3 to 2.6 mm. long, corolla lobes more oblong in shape, less densely pubescent outside; calyx tube almost lacking, calyx lobes less reflexed, sharper at apex ..16a. *A. angustifolia* var. *annamensis*
- 8(3). Leaves with principal lateral nerves close, averaging 3 to 6 mm. apart near middle of blade. Australia.....
- .....19. *A. ophioxylodes*
- Leaves with principal lateral nerves more distant, averaging 6 to 12 mm. apart. Java to Australia and elsewhere.....18. *A. spectabilis*
- 9(2). Corolla lobes ligulate, 3.5 to 7 mm. long and less than half as broad, about as long as corolla tube.....10
- Corolla lobes oval, 2 mm. long and half as broad,  $\frac{2}{3}$  as long as corolla tube, ciliate only at base; leaves glabrous. New Guinea. (Not seen.).....23. *A. glabriflora*
- 10(9). Pedicels comparatively long and slender, up to 4 mm. long; calyx less than 1.5 mm. long, the lobes about 1 mm. or less long, gray-puberulent or glabrous outside; stamens inserted near throat of corolla tube; leaves pubescent or glabrous beneath. Philippines to Malaya .....11
- Pedicels short and stouter, less than 3 mm. long; calyx about 2 mm. long, the lobes over 1.5 mm. long, glabrous or nearly so outside; stamens inserted near middle of corolla tube; leaves glabrous. New Guinea.....22. *A. Brassii*
- 11(10). Calyx lobes usually less than 1 mm. long, puberulent as well as ciliate; anthers about 0.9 mm. long.....
- .....21. *A. macrophylla* (typical)
- Calyx lobes usually more than 1 mm. long, ciliate, otherwise glabrous, sharper at apex; anthers about 1.1 mm. long. Amboina and Ceram....
- ..21a. *A. macrophylla* var. *acuminata*
- Section DISSURASPERMUM (A. Gray) Benth., in Benth. and Hook., Gen. Pl. 2: 705. 1876.
- Subgen. *Dissuraspermum* A. Gray, in Proc. Amer. Acad. 5: 334. 1862.
- Series *Orientales* Pichon, in Paris Mus. d'Hist. Nat., Bul. II, 19: 298. 1947.
- Small trees or shrubs. Leaves opposite, rarely also 3-verticillate, lateral nerves distant or close, reticulation manifest or obscure. Corolla lobes with right margins overlapping; disc not apparent. Follicles separate; seeds elliptic, usually caudate at both ends, sometimes merely acuminate; tails often forked, faces pubescent, margins and tails short-ciliate with hairs more or less equal in length, not comose-ciliate; placental scar short.
- Type species.—Gray furnished an adequate description of this group and cited as representative species, *A. costata* and *A. plumosa*. The older species, *A. costata* (Forst. f.) R. Br., is proposed as the type of the section.
- Key to Section *Dissuraspermum*
1. Calyx lobes manifestly ciliate; seeds lanceolate, 7 to 12 mm. long, hardly caudate. Plants of Australia ..... 25. *A. constricta*
- Calyx lobes not ciliate. Plants not of Australia ..... 2



- 2(1). Corolla lobes manifestly ciliate; inflorescence very sparsely and loosely flowered; leaves with numerous lateral nerves (about 40 pairs); seeds about 16 mm. long, slender-caudate at both ends. New Caledonia.....26. *A. lanceolata*  
Corolla lobes not ciliate or very obscurely and sparsely so..... 3
- 3(2). Corolla tube minutely puberulent outside near middle, 8 to 9 mm. long, corolla lobes shorter than tube; inflorescence with branchlets and pedicels adpressed or ascending; leaf blades 9 to 36 cm. long and 4 to 22 cm. broad, dull on upper surface, not retuse at apex; seeds 7 to 9 mm. long, the tails short, less than 2 mm. long. New Caledonia.....27. *A. Vieillardii*  
Corolla tube glabrous outside, less than 7 mm. long..... 4
- 4(3). Inflorescence strongly divaricate, lax; corolla tube 2 to 3 mm. long; leaves with about 30 or more pairs of lateral nerves. New Caledonia. (Species not seen.)..... 5  
Inflorescent branches divaricate to erect; combination of characters not as above. Species difficult to distinguish; best recognized by combination of many characters. (Species seen, except *A. plumosa*.)..... 6
- 5(4). Leaf blades linear-lanceolate, 5 to 9 cm. long and 0.5 to 0.8 cm. broad; branches slender. (Not seen.).....37. *A. saligna*  
Leaf blades oblong-oblancoate, 12 to 25 cm. long and 3 to 6 cm. broad. (Not seen.).....38. *A. Comptonii*
- 6(4). Seeds 12 to 24 mm. long, slender-caudate at both ends, tails long, 4 to 9 mm. long, fork distant from body of seed; principal lateral nerves up to 25 pairs..... 7  
Seeds 4 to 12 mm. long, short-caudate, tails 1 to 4 mm. long, forked near body of seed; leaves glabrous.....11
- 7(6). Leaf blades 2.5 to 11 cm. long and 1.2 to 3.5 cm. broad, rounded to somewhat acute at apex; corolla lobes oblong, pubescent the entire surface within; follicles 7 to 13 cm. long; seeds 24 mm. long. New Caledonia. (Not seen.).....29. *A. plumosa*  
Leaf blades larger or seeds shorter..... 8
- 8(7). Leaf blades 14 to 28 cm. long and 3 to 15 cm. broad, usually acuminate at apex, glossy above, lateral nerves 16 to 25 pairs; corolla lobes oblong-lanceolate; follicles up to 22 mm. long. Plants of New Caledonia.....28. *A. Roeperii*  
Leaf blades dull to somewhat shining above, lateral nerves 10 to 17 pairs; corolla lobes linear-lanceolate. Plants not of New Caledonia..... 9
- 9(8). Branchlets usually very stout, petioles 2.5 to 9 cm. long, usually conspicuously fossate at axil; leaf blades often very large (6-) 8 to 45 cm. long and 4 to 27 cm. broad, lateral nerves (10-) 12 to 16 pairs.....10  
Branchlets not stout; petioles 1.5 to 3 cm. long, not conspicuously fossate at axil; leaf blades usually 7 to 20 cm. long and 3 to 9 cm. broad, glabrous or rarely villose beneath, lateral nerves usually 10 to 13 pairs. Transitional species.....31. *A. Reineckea*
- 10(9). Leaf blades elliptic, usually rounded to short-acuminate at apex and rather obtuse at base; corolla tube 2.2 to 4.4 mm. long. Solomon Islands to Fiji and Samoa.....30. *A. vitiensis* (typical)  
Leaf blades lanceolate, usually greatly narrowed at apex and base; corolla tube 2.2 to 3 mm. long. New Hebrides.....30a. *A. vitiensis* var. *novo-ebudica*
- 11(6). Leaf blades oblanceolate, about 3 to 4.5 cm. long and 1.2 cm. broad, retuse at apex, lateral nerves ascending, about 14 pairs; inflorescence short, sparsely flowered, branches rather erect; corolla tube about 6 mm. long, corolla lobes 2.5 mm. long, faintly pubescent outside; stamens inserted near base of corolla tube. New Caledonia.....34. *A. Deplanchei*  
Leaf blades rounded to acuminate at apex, rarely slightly retuse; corolla tube 2 to 6 mm. long, corolla lobes glabrous outside.....12

- 12(11). Leaves usually ternately verticillate as well as opposite, thickly coriaceous; petioles 0.5 to 1 cm. long; blades 5 to 7 cm. long and 1.2 cm. broad, lateral nerves obscure; inflorescence with ascending branches, flowers numerous and crowded. New Caledonia.....  
.....36. *A. Legouixiae*  
Leaves opposite (never ternate?); inflorescent branches spreading....13
- 13(12). Lateral nerves of leaves straight, horizontal, 22 to 30 pairs; inflorescent branches filiform; calyx 0.7 to 1.4 mm. broad below lobes, the lobes 0.6 to 1 mm. long; anthers 0.7 to 0.8 mm. long. New Caledonia.....14  
Lateral nerves of leaves arcuate, 11 to 22 pairs; inflorescent branches usually stouter, calyx larger; anthers 0.9 to 1.6 mm. long. Fiji to Society Islands .....16
- 14(13). Corolla lobes narrowly lanceolate to oblong-lanceolate, 2.8 to 5 mm. long and 0.8 to 1.3 mm. broad.....15  
Corolla lobes broadly ovate, 2.2 to 2.4 mm. long and 2.2 to 2.8 mm. broad .....  
35b. *A. Lenormandi* var. *lanceolifera*
- 15(14). Leaves chartaceous, rounded or slightly retuse at apex, the reticulation manifest .....  
.....35. *A. Lenormandi* (typical)  
Leaves coriaceous, obtuse to slightly acuminate at apex, the reticulation obscure .....  
.....35a. *A. Lenormandi* var. *coriacea*
- 16(13). Leaf blades 5 to 15 cm. long and 2.5 to 6 cm. broad, usually obtuse or rounded at apex; inflorescence usually few-flowered; calyx lobes ovate, 0.9 to 1.6 mm. long; seeds 7 to 10 mm. long, tails 2 to 4 mm. long. Fiji and Samoa.....17  
Leaf blades 9 to 21 cm. long and 1.5 to 10 cm. broad, usually abruptly and sharply long-acuminate at apex; inflorescence usually many-flowered; calyx 1.2 to 2 mm. broad below lobes, the lobes ovate-lanceolate, 2 to 3 mm. long; seeds 4.5 to 7 mm. long, tails 1 to 3 mm. long. Society Islands and Marquesas .....33. *A. costata*
- 17(16). Calyx 1.4 to 2.6 mm. broad below lobes; inflorescence without fili-

form branches .....

- .....32. *A. montana* (typical)  
Calyx 1 to 1.3 mm. broad below lobes; inflorescence with filiform spreading branches and pedicels....  
.....32a. *A. montana* var. *filiformis*

#### Section not known

Corolla lobes with right margins overlapping; ovary characteristically ridged, style very short, ovules in two ranks in each cell; leaves 4-verticillate, petioles 2 to 4.5 cm. long, blades 8 to 16 cm. long, lateral nerves numerous (35 to 60 pairs) and close, reticulation not clear. New Caledonia.....  
.....39. *A. quaternata*

#### § WINCHIA

This section is monotypic.

1. *Alstonia glaucescens* (K. Schum.) Monachino, comb. nov.  
*Alyxia* ? *calophylla* Wall., Num. List. no. 1607. 1829. —nom. nud.<sup>3</sup>  
*Alyxia glaucescens* G. Don, Gen. Sys. of Gard. 4: 97. 1837 (as to cit.); non. Wall. in Roxb., Fl. Ind. 2 (ed. 1): 542. 1824.  
*Winchia calophylla* A. DC., Prod. 8: 326. 1844.  
*Winchia glaucescens* K. Schum., in Engl. and Prantl, Pflanzenf. 4(2): 125. 1895.  
*Alstonia rostrata* C. E. C. Fischer, in Kew Bul. 1929: 315. 1929.  
*Alstonia pachycarpa* Merrill and Chun, in Sunyatsenia 2: 98. 1934.

Trees up to 25 m. tall and 80 cm. in diameter. Leaves 3- or 4-verticillate, the petioles 1.5–3 cm. long, the blades elliptic, 9–13 (–20) cm. and 3–5 cm. broad, bluntly acuminate at apex, shining above, slightly paler beneath, not glau-

<sup>3</sup> There is some variance among authors in the precise usage of the designation *nomen nudum*. It is here used in its broadest definition, as suggested in the Index Analytique of the 1906 ed. of the International Rules: "noms publiés sans diagnose imprimée ou sans son équivalent." Merrill, A. C. Smith, Rehder, Pennell, Kobuski, and many others have referred to the well-typified names appearing in Wallich's Num. List as *nomina nuda*. Other botanists recommend that these names of Wallich be designated hyponyms, the term *nomen nudum* being reserved for mere names that appear without reference or any characterization whatsoever.



cescent-pallid, the margins involute, the lateral nerves 30–50 pairs, 2 mm. apart, the reticulation prominulous on both surfaces. Inflorescence in rather lax many-flowered cymes, glabrous, the peduncles short, 1.5–2 cm. long, the pedicels up to 3 mm. long, glabrous; calyx lobes ovate, 0.7–1.4 mm. long, glabrous or sparsely puberulent outside, adpressed pubescent inside, ciliate; corolla tube 5–6 mm. long, sparsely puberulent on upper part outside; corolla lobes broadly elliptic, 3–4 mm. long and about 2.5 mm. broad, puberulent outside, villose inside particularly toward base where densely bearded; anthers 1–1.5 mm. long, not dehiscent completely to base, located at throat of corolla, the filaments attached manifestly above middle of corolla tube; ovary partly inferior, rounded at apex, glabrous or faintly puberulent; stigma-apiculi about 0.5 mm. long. Capsule about 1 cm. in diameter; seeds 9 mm. long and 3 mm. broad, the cilia up to 2 cm. long.

TYPE.—Wall. Num. List. no. 1607, "Martabania 1827."

ILLUSTRATIONS.—DeLessert, Icon. Select. Pl. (1846) 5: t. 46 (as *Winchia calophylla*) leafy br. and infl., fl. analysis; Sunyatsenia (1935) 2: 310, fig. 42 (as *A. pachycarpa*) leafy br., fr.

DISTRIBUTION.—China, Burma, Sumatra; reported frequent or rare, from altitudes of 300–1100 m., in forests, woods, thickets, clay cliffs.

China—Yunnan: *C. W. Wang* 75807, 77850, 75927, 79160 *A* (fr.; *A*). Hainan: *S. K. Lau* 1630 (Ka Chik Shan; fl.; NY, *A*), 27600 (Kumyun; fr.; *A*); *Chun and Tso* 44317 (type coll. *A. pachycarpa*; *A*, *K*, NY, US).

Lower Burma—*Wallich* 1607 (type coll. *Winchia calophylla*; NY); *C. E. Parkinson* 6297 (Mergui, Victoria Point; fl.; *K*), 6563 (type coll. *A. rostrata*; *K*), 7684 (Mergui; fr.; *K*).

Sumatra—*Boschproefst.* 5977 (Res. Sum. Westk. and afd. Loeback Sikaping; *L*).

VERNACULAR NAMES.—*Dit Sz Mou* (Hainan), *Boelai Pipit* (Sumatra), *Taung-ma-yo* (Thaton).

In the selection of the proper specific epithet

to be employed for the present species considerable differences in opinion were encountered. Therefore the reason for my choice is presented at length.

*Alyxia glaucescens* G. Don is associated with the present species only in Don's citation of Wall. List. 1607. Don's description and allocation ("straits of Malaca") identify his plant with Wallich's species from Penang, the *Alyxia glaucescens* in Roxburgh's *Flora*, which is not an *Alstonia*. Whether it be considered a later homonym or *nomen confusum*, or both, or a typographical error in accrediting the name to himself rather than to Wallich, *A. glaucescens* G. Don has no standing.

The specific epithet *calophylla* has been appropriated by Miquel for his *Alstonia calophylla*, a species placed in synonymy of *A. angustiloba* in the present paper.

Now the question arises whether *Winchia glaucescens*, which is the next name in order of priority, is legitimate. Schumann observed that since the name *Alyxia glaucescens* G. Don was cited by De Candolle in synonymy of *Winchia calophylla* A. DC., the earlier specific epithet should be used; he apparently considered his name a new combination in which use was made of Don's epithet, and he accredited G. Don parenthetically. Actually De Candolle had noted that *A. glaucescens* G. Don differed from his plant in some important characters but referred to it primarily because of Don's citation of Wall. 1607. However, Schumann's description of the Martaban plant and his placing of *Winchia calophylla* in synonymy leave no doubt regarding what species he had in mind. Schumann erred merely in considering Don's specific epithet as being necessary for a new combination, for it was illegitimate and therefore not to be taken into consideration for the purpose of priority. The question is whether Schumann could legitimately make use of *glaucescens*. The answer is yes; for the International Rules (Ed. 3, 1935. Article 69) concede as proper for the formation of a new name the employment of an epithet that has been illegitimately

published: "Where a new epithet is required, an author may, if he wishes, adopt an epithet previously given to the group in an illegitimate combination, if there is no obstacle to its employment in the new position or sense." The example given is as follows: *Talinum polyandrum* Hook. (1855) is illegitimate, being a later homonym of *T. polyandrum* Ruiz and Pav. (1798). *Calandrinia polyandra* Benth. (1863), not as a new combination, but as a new name, is legitimate. Bentham's name given as an example by the Rules was published in *Flora Australiensis* 1: 172, where a description of the plant was given followed by "*Talinum polyandrum* Hook. Bot. Mag. t. 4833" in synonymy. Clearly, this example is almost identical with that of *Winchia glaucescens*, inasmuch as in both instances the name was accompanied by a description and the specific epithet was borrowed from an illegitimate name with the intention of forming a new combination. Therefore, *Winchia glaucescens* was a legitimate new name and as such is the earliest binomial having a specific epithet which must be used for the present plant.

There is one difference between the case of *Winchia glaucescens* and that of *Calandrinia polyandra*. There is good reason to believe that Schumann was not aware that Don's *Alyxia glaucescens* was illegitimate; he was motivated not by choice but entirely by his understanding of the requirements of priority. Likewise, Bentham most probably was not aware that *Talinum polyandrum* Hook. was a later homonym, but the evidence for believing this is not as direct as in Schumann's case. It is conceivable that had Schumann understood the poor position of Don's name he would not have adopted Don's inadequate specific epithet. In such a case, by attributing *Winchia glaucescens* to him we would be forcing him, perhaps against his "wish," to be responsible for a name he would have abjured had he known that choice was left to him. Adding the phrase, "if he wishes," to the author's prerogative, does not help to clarify the meaning of Art. 69.

Type of *A. rostrata*.—"Thaton, Yatheyaung, 2500 ft., flowers Mar., *P. Chin* per *C. E. Parkinson* 6536 (type), vernacular name *Taung-ma-yo*; Mergui, Victoria Point, 75 ft., flowers Jan., *Sukoe* per *C. E. Parkinson* 6295; fr. Mar., *Sukoe* per *C. E. Parkinson* 7684 (type for fruit.) (Burma)." The collector's number appearing on the type collection is 6563.

Type of *A. pachycarpa*.—"Hainan: Ting-on, Mocheung Ling, *N. K. Chun* and *C. L. Tso* 44317. Nov. 22, 1932; a large tree up to 25 m. high, the trunk 80 cm. in diam., in forests, alt. 600 m."

### § PALA

Leaves almost always glabrous, the marginal nerve usually clear; corolla tube about 1 cm. or less long; anthers about 0.7–1.6 mm. long, usually not dehiscent to extreme base; style long and slender; ovary usually superior; follicles long; seeds about 8 mm. or less long, 1–2 mm. broad.

Common throughout the range of the genus except in the far eastern Pacific.

2. *Alstonia scholaris* (L.) R. Br., in Mem. Wern. Soc. 1: 76. 1811.

"*Pala*" Rheede, Hort. Malab. 1: 81, t. 45. 1678.

"*Nerium lactescens malabaricus platyphyllum* ..." Breyn., Prod. 2: 86. 1739.

"*Lignum scholare*" Rumph., Amb. 2: 246 [t. 82?]. 1741.

*Tabernaemontana citrifolia* L., Sp. Pl. 1: 210. 1753; as to cit. "*Pala* Rheede." Hill ed., Hort. Mal. 1: t. 46 [non diagnosis]. 1774. *Echites scholaris* L., Mant. 53 [non cit. t. ?]. 1767.

*Tabernaemontana alternifolia* Burm., Fl. Ind. 69. 1768; as to cit. pro part.

*Aeschynomene laevis* Noronha, Verh. Batav. Genootsch. 5: 68. 1790; nom. nud. [Syn. fide Miquel.]

*Echites* ? *Pala* Ham., in Trans. Linn. Soc. 13: 518. 1822.

*A. scholaris*  $\beta$  *Blumii* A. DC., Prod. 8: 409. 1844.



*A. scholaris*  $\gamma$  *Avae* A. DC., Prod. 8: 409. 1844.

? *A. Kurzii* Hook. f., Fl. Brit. Ind. 3: 643. 1882.

Trees up to 40 m. tall and 1.25 m. in diameter. Petioles about 2 cm. (up to 3 cm.) long. Leaf blades spatulate or oblanceolate, rarely elliptic, 7–28 cm. long and 2–11 cm. broad, usually rounded at apex, rarely bluntly acuminate; shining above; the lateral nerves 40–50 pairs, 3–5 mm. apart, the reticulation and transverse veins prominent on upper surface, the marginal nerve prominent. Inflorescence in dense cymes, many-flowered, pubescent, the pedicels short. Calyx lobes ovate to lanceolate, 1–3 mm. long, pubescent outside and sparsely so inside; corolla tube 6–10 mm. long, densely to sparsely pubescent outside; corolla lobes quadrate-orbicular, 2–4.5 mm. long and about as broad, undulate-margined, pubescent on both sides; anthers 0.9–1.3 mm. long; ovary densely hirtellous; follicles sparsely hirtellous, sometimes glabrous. Seeds lightly muricate-roughened.

TYPE.—Citation by Brown: "*Pala*, Reed mal. 1. p. 81, t. 45. optima. *Lignum scholare*, Rumph. amb. 2. p. 246. t. 82. quoad descriptionem, sed figura potius sequentis. *Echites scholaris*, Linn. mant. 53. Hab. In India Orientali et in Insulis Moluccanis. (v. s. in Herb. Banks)." *Echites scholaris* is based on "*Lignum scholare*" Rumph., Amb. 2: 246, t. 82.

Rumphius' description of *Lignum scholare* is in agreement with *Alstonia scholaris*. "In omnibus aquosae Indiae insulis nota," the plant is identified with *Pala* "In Horto Malabarico tom. 1. Fig. 45," which is unquestionably *A. scholaris*. Linnaeus' *Echites scholaris* rests principally on Rumphius' *Lignum scholare*, although his short description is in fair agreement with *A. scholaris*. A discordant element, however, appears in the figure representing "*Lignum scholare*," plate 82 of Rumphius' *Herbarium Amboinense* which depicts an *Alstonia* with leaves sharply pointed at the apex (described as "obtusio apice") and with about 12 pairs of principal lateral nerves (described as "plurimis parallelis costis"). This

illustration diverges widely from *A. scholaris*, but is not adequate for precise identification. It is noted by Brown to be rather of *A. spectabilis*; the leaves are 4- to 6-verticillate, otherwise there is strong justification for Brown's observation. The inflorescence as represented is fair for either *A. scholaris* or *A. spectabilis*. Hamilton in 1822, presumably on the basis of this figure, held "*Lignum scholare*" as distinct from "*Pala*," and named the latter, which he thought unoccupied, *Echites Pala*.

ILLUSTRATIONS. — Philippine Jour. Sci. (1926) 31: t. 1–6, fig. 1–41 (leafy br. and infl., fl., fr., seed, bark, bark anatomy); Koord. and Val., Atl. Baumart. Java (1913) t. 77 (leafy br., infl., fl. analysis, fr., seed, tree habits); Benth. and Trim., Med. Pl. (1880) 3: t. 173 (leafy br. and infl., fl. analysis, fr., seed); Kirtikar (ed. Basu), Ind. Med. Pl. (1918) t. 606 (leafy br. and infl., fr., fl. analysis, seed); Engl. and Prantl, Nat. Pflanzenf. (1895) 4(2): 138, fig. 53 (leafy br. and infl., fl. analysis, fr., seed); Rheede, Hort. Mal. (1678) 1: t. 45 (leafy br., and infl., leaf, fl., fr., seed); Wight, Ic. Pl. Ind. Or. (1843) 2: t. 422 (leafy br. and infl., fl. analysis—leaf shape and nerves not representative); Ahern, Philippine Woods (1901) 46 (leafy br. and fr., infl.—leaf shape and nerves not representative).

DISTRIBUTION.—The most widely distributed species of *Alstonia*: from India to southern China, south to Malaya and the entire area of Malaysia, east to Queensland and the Solomon Islands. Reported from Liukiu, Yayeama, by Matsumura (Index Pl. Jap. 2: 505. 1912). Grows at 0–1000 m. or more altitude and is tolerant of a variety of soils and habitat.

India—*Anstead* 94 (Mangalore; A); *Biswas* 1675 (Bengal; A); *Calcutta herb.* (Calcutta; GH); *Dewan* 82 (Nakrunda; G); *Erlanson* 5310 (Travancore); *Gibson* (Bombay; P); *Hobenacker* 295 (Canora; G, P); *Hooker* (Bengal; L); *Jenkins* (Assam; G); *Mukherjee* 78 (Nakrunda; US); *Roxburgh* (G); *Wallich* 1644, 1644a (Nepal; G); *Wight* 2540; *Stachey and Winterbottom* (Kumaon; GH).

Ceylon—*Burmann* (G).

Burma—*Bur. For. School Herb.* 34 (US), 36 (A), 67 (F); *J. F. Smith* 41 (Rangoon; GH).

Siam—*Collins* 1935 (Bangkok); *Kerr* 3412 (Doi Sute; BM), 5125 (Chieng Ra; A), 13528 (Bangkok; BM), 13848 (Satul; BM), 15025 (Ban Sai Kao; A); *Marcan* 2298 (Bangkok; BM); *Put* 3701 (Yala; BM).

Indo-China—*Balansa* 4729 (Tonkin; A); *Bon* 6190 (Tonkin; A); *Clemens* 3869 (Annam); *Petelot* 5985 (A); *Poillane* 1223 (Annam; A), 6626 (Annam); *Tsang* 27098 (Taai Wong; A).

China—*Morse* 159 (Kewi Chow; BM, K); *Wong* 12 (Kwantung).

Malay Peninsula—*Corner* (Kelatan; Sing); *Curtis* 2352 (Selangor; Sing); *Hanad* (Selangor; Sing); *Holltum* (Pahang); *King's Coll.* 7952 (Perak; Sing); *Kunstler* (Perak; Sing); *Watson* 5835 (Johore; Sing).

Sumatra—*Boschproefst.* 6610 (Pajacombo; leaves dried an unusual yellowish-green, sterile; L), 8004 (Lampongs; L); *Vries and Teysmann* (L); *Zollinger* 3393 (L).

Java—*Backer* (Batavia; L); *Elbert* 354 (Madioen; L); *Junghuhn* (L); *Koorders* 9 (Bantam; L), 10 (Preanger; L), 11 (Madioen; L), 14 (Semarang; L), 16 (Soerakarta; L), 18 (Banjoemas; L), 19 (Tegal; L), 21 (Pekalongan; L), 23 (Madioen; A), 25 (Besoeke; L), 27 (Djember; L), 25535 (Semarong; L), 28201 (Telawan; L), 37222 (Djapara; L); *Merrill* (cult. IV-A-40; IV-A-46; IV-A-61); *Neth. Ind. F. S.* (Bondowoso; A); *Sargent* (cult. IV-A-84; A); *Teymann; Wisse* 753 (Madioen; L); *Zollinger* 3567 (G, K), 3567 (BM).

Bali—*Becking* 29 (L).

Timor—*Herb. Lug. Bat.* (L); *Herb. Mus. Paris* (G, L).

Borneo—*Clemens* 30883, 30884 (Mt. Kinalu; sterile; G, A); *D. D. Wood* 1914 (Brit. N. Borneo; UC).

Philippines—Luzon: *Clemens* 18819 (UC); *Cuming* 1229 (G, L, Mo); *Elmer* 8165; *For.*

*Bur.* 746, 1416, 2682, 17307, 18595 (Bish), 25671 (A), 25867 (F, Mo), 28853 (G); *Merrill Sp. Blancoanae* 232; *Perrottet* (L). Bala-bac: *Bur. Sci.* 427.

Celebes—*Boschproefst.* 63 (L), 141 (L); *De Vries and Teysmann* 46 (L); *Koorders* 1607 (L), 15803 (L), 16043 (L), 19735 (L); *Neth. Ind. For. Ser.* 21595; *Teymann* 12516 (L).

Ternate—*Beguín* 665 (L), 1658 (infl. unusually lax; L).

Soelabesi—*Hulstijn* 403 (L).

Boeroe—*De Vries* (L).

Amboina—*Neth. Ind. For. Serv.* 25997 (Mo); *Kornassi* (L).

Ceram—*Neth. Ind. For.* 19650 (L).

Banda—*Herb. Lugd. Batav.* 178 (L); *Boschproefst.* 13434 (L); *De Vries and Teysmann* (L); *Hallier f.* 45 (cult.; L).

Netherlands New Guinea—*Brass and Versteegh* 14013; *Neth. In. For. Serv.* 30499 (Japan; A), 30525 (Japan; A), 30664 (Japan; Mo).

Papua and Northeastern New Guinea—*Carr* 11357 (Kanosia); *Brass* 686 (Papua; A), 8335 (Gaima; A); *Ledermann* 7858 (Sepik; Sing); *Waterhouse* 317 (Gazelle Pen.).

Queensland—*Herb. F. D. Mueller* (GH); *Queens. For. Ser.* 88, C. T. White (A).

Bougainville—*D. H. Johnson* (A); *Waterhouse* 111.

Puerto Rico—*Cobin* (cult.).

Dominica—*L. H. Bailey* 213 (Bot. Gd.; A).

VERNACULAR NAMES.—See Heyne, *Die Nut. Pl.* (1927) 2: 1277. The following are some additional local names. India: *Chhatian*, *Eda-Kula*, *Saptaparni*, *Satwin*, *Shaitan*; Siam: *Ton Tinpet*; Indo-China: *Cay Mua Cua*, *Cay Phao Luoi*, *Cay Sua*, *Cay Vo Cua*, *Mo Cua Trang*, *Mu Cua*; Borneo: *Poelanten Boeboor*; Talaud Islands: *Karakelong*, *Pampoeloeta*, *Pamperoeda*; Philippines: *Dita*, *Dalipaoen*; New Guinea: *Aijapa*, *Amika*, *Devoru*, *Didima*, *Itig*; Bougainville Island: *Kingiri*, *Sinivi*, *Tangovo*, *Uajii*; Queensland: *Milkwood* or *White Pine*.

Breynius' "*Nerium lactescens* . . ." is based on "*Pala*" *Horti Malabarici*.



Under *Tabernaemontana citrifolia*, Linnaeus cited "Hort. Cliff. 76, Roy. Lugdb. 413; Plum. gen. 18; *Pala* Rheed. mal. 1. p. 81. t. 46." The citation of "t. 46" for *Pala* is an error for "t. 45." Only because of its reference to *Pala* is the name listed under *A. scholaris*. *T. citrifolia* in Hill's 1774 edition of *Horti Malabarici* is given to figure 46, which is a copy, in part, of figure 45 in the 1678 edition; the description here is also copied from Rheede, but the diagnosis refers to the Linnaean species.

Under *Tabernaemontana alternifolia*, citation was made of "Breyn. prodr. 2, p. 86; *Lignum scholare* Rumph. amb. 2 p. 246, t. 82" and "*Curutu-pala* Rheede mal. 1, p. 83, t. 46." The name is listed under *A. scholaris* principally because of its reference to *Lignum scholare* and partly because of its reference to Breynius' work (see *Nerium lactescens*, etc.).

The only information Noronha gives for *Aeschynomene laevis* is that it is a new species bearing the Javanese name "Caju Gabus." It here appears in the synonymy of *Alstonia scholaris* entirely on the authority of Miquel. The Malayan name "Kajoe Gaboes" is sometimes applied to *A. scholaris* (fide K. Heyne).

Type of *A. scholaris*  $\beta$  *Blumii*.—"In Java (Blum. bijdr. p. 1037)." Blume described this as "*A. scholaris* variet.," without varietal name, and stated: "ad pedem montis Salak . . . foliis cuneato-oblongis obtusis, umbellis effusis." The indications are that this variety was based on a trivial variation in leaf shape. It is unlikely that it was confused with *A. spatulata*, for Blume knew this species, he himself having published it. There is no evidence that it is *A. pneumatophora*, which also has cuneate leaves. The latter is either rare or lacking in Java; its leaves are almost identical with those of *A. spatulata*, and it is presumed that Blume would have noted the foliage similarity if the variety before him had been *A. pneumatophora*.

Type of *A. scholaris*  $\gamma$  *Avae*.—"In montibus Tong-Dong prove Avam. *A. scholaris* Wall. list 1644. f." Ava is in Burma, and according to

Wall. Num. List, 6th citation under 1644, the Toong plant was collected by William Griffith. This variety apparently was based on a trivial variation in leaf shape; "foliis elongatis. Folia 6-8 poll. longa,  $1\frac{1}{2}$ - $2\frac{1}{4}$  poll. lata, apice angustata obtusiuscula."

Type of *A. Kurzii*.—"Forests of the Andaman Isls., Kurz." Hooker placed this under "Species of Doubtful Position," and stated that it was the "*A. spectabilis* Kurz For. Fl. 2: 183, not of Brown." Hooker's description obviously is derived from Kurz. The only character adduced to distinguish this species from *A. scholaris* is the "quite glabrous" inflorescences or the "glabrous panicle." Kurz (1877: 254) noted that it is "hardly specifically distinguishable from *A. scholaris*." The density of pubescence in the inflorescences of *A. scholaris* varies greatly, but I have never seen any specimen completely glabrous.

*Alstonia oleandraefolia* Lodd. ex Loud., Hort. Brit. (1830) 67, is referred to *A. scholaris* by G. Don (1837: 86) and in the Index Kewensis. In Hort. Brit., *A. oleandraefolia* is listed without description and *Nerium tinctorium* Hort. is cited in synonymy. *Nerium tinctorium* Hort. ex Sweet, Hort. Brit. ed. 1. (1826), 274, was published merely as a synonym of *Allamanda verticillata* Desf. ex Spreng. The description of the latter in Sprengel's Syst. is inadequate for precise identification. Desfontaines (1815) listed *Allamanda verticillata* under the heading "Germen simplex, fructus baccatus aut rarius capsularis." From this characterization it is clear that *Allamanda verticillata* is not an *Alstonia*, and consequently neither is *Alstonia oleandraefolia*.

*Nerium tinctorium* Hort. ex Sweet has been placed in synonymy, under *A. scholaris*, by G. Don (1837: 86) and others. As shown above, there is no justification for associating the two names. C. B. Robinson (1908: 306) states that *Nerium tinctorium* in Perrottet (1824: 132) is from description probably *Alstonia scholaris*. Following this lead, Merrill (1923:

323) made "*N. tinctorium* Perr." a straight synonym of *A. scholaris*. Perrottet's casual description (tree 6–10 m. tall, with opposite leaves which are soft to the touch) hardly suggests *A. scholaris*; the characters given agree better with those of *Wrightia*. The illustrations cited by Perrottet ("Hort. Malab. 1: t. 46 and 2: t. 54 and 55") are not of *Alstonia*, unless by the first citation reference was made to plate 46 of Hill's edition of *Hortici Malabarici*. The brilliantly colored blue dye furnished by the leaves of the plant Perrottet had in mind excludes *Alstonia*, but rather points to *Wrightia*. Roxburgh was thoroughly acquainted with the indigo qualities of *Wrightia tinctoria* and is reported to have transmitted a sample of the dye to England in 1792. A specimen deposited at the New York Botanical Garden (Perrottet 325, from Pondicherry) is *Wrightia tinctoria*. The combination *Nerium tinctorium* was first published by Roxburgh in 1803 (Berlin Ges. Nat. Freunde N. Sch. (1803) 4: 198).

*Echites malabaricus* Lam., which is referred to *A. scholaris* in the Kew Index and dubiously to *Echites Pala* by Sprengel, is not an *Alstonia*.

Hamilton (1822: 517) erroneously credits the name "*Tabernaemontana scholaris*" to Linnaeus and Burmann.

2a. *Alstonia scholaris* var. *velutina* Monachino, var. nov.

A forma typica speciei foliis pubescentibus recedit.

Leaves velutinous beneath. Corollas in type less pubescent outside than in typical *A. scholaris*.

TYPE.—*R. E. Holttum* (Singapore Field no. 24680), Malay Peninsula, state of Pahang, Tekal; April 22, 1931. (Singapore.)

Foliage indumentum in the § *Pala* is very unusual. Of the numerous specimens of *A. scholaris* examined (over 300), this variety is the only pubescent one; the others, and also the collections seen in other species in the section, have completely glabrous leaves.

3. *Alstonia Boonei* De Wild., in Fedde Repert. 13: 382. 1914.

Very closely resembling *A. scholaris* in vegetative and floral characters, but flowers on longer pedicels and more loosely disposed, and follicles tomentose.

TYPE.—"Belgisch-Kongo: Environs de Nala, 1911 (Boone)."

ILLUSTRATIONS.—Chevalier, La Geog. Bot. et Fl. Econ. du Senegal et du Soudan (1900) 207 (as *A. scholaris*; photo of leafy br. and infl.); Eggeling, The Indig. Trees of the Uganda Protector. (1904) t. 2 (as *A. congensis*; photo of tree showing habit and habitat).

DISTRIBUTION.—West tropical Africa, Angola to Gambia, and easterly to Uganda and Sudan; sometimes abundant.

Congo—Boone (type; Br); Bequaert 1790 (Avokubi; Br); Briey 17 (Br); Cabra 63 and 72 (Br); Claessens 113 and 379 (Br); Coulon 3 (Bodala; Br); Dawe 243 (Angola; K); Dewulf 342 (Bas Uele; Br); Gillardin 149 (Bakuba; Br); Gossweiler 6611 (Angola; BM), 6788 and 8012 (Cabinda; K); Laurent (Lusambo; Br); Lemaire 6 (Bangola; Br); Louis 1184 (Belg.; Br), 3057, 3127, 6206, 9507, 13538, 13825 (Yangambi; Br), 13849 (Weko; Br); Mortebean 973 (Dundusana; Br); Pynaert 334 (Br); Reygaert 976 (Mobwasa; Br); Robyn 1348 (Bamabia; Br, G, K); Vermoesen (Br), 1443 (Mayombe; Br).

Uganda—Cons. For. 4422 (A); Eggeling 1546 (US), 1547 (BM), 1548; Harris 403–405 (K).

Sudan—Chevalier 2690 (G, L); Schweinfurth 3260 (Niamniam; K); Thomas 1761 (K); Turner 157 (Azza; K).

Cameroons—Lehman (Lolodorf; K); Mildbraed 10708 (N.E. Victoria; A); Zenker 433 (Bipindi; G, GH, Mo, NY, UC, US), 1622 (Bipindi; K, L).

Nigeria—Foster (Lagos; K); Kennedy 1956, 2393 (A), 2084 (BM, K); McLeod (K); Punch 137, 145 (Lagos; K).

Gold Coast—Brown 2355 (Kumasi; A); Deighton 3416 (Aburi; K); Irvine 1851 (Ku-



masi; K); *Kitson* 1019 (Ankobra; K).

Ivory Coast—*Chevalier* 15194 (Bingeroville; G).

Sierre Leone—*Deighton* 2993 (K); *Thomas* 3934 (K).

Gambia—*Dawe* 37 (K).

VERNACULAR NAMES.—Belgian Congo: *Guga*, *Okuka*; Mayombe: *Songoti*; Bunyoro: *Mujwa*.

This species is in many respects more closely related to *A. scholaris* than it is to *A. congensis*. It might be conceived as an African variety of the former. The three form a closely knit unit.

The greater part of the material distributed as *A. congensis* belongs to this species.

4. *Alstonia congensis* Engl., Bot. Jahrb. 8: 64. 1886.

*A. Gilletii* De Wild., Miss. É. Laurent. 1: 537. 1907.

*A. Gilletii* var. *Laurentii* De Wild., Miss. É. Laurent. 1: 537. t. 162. 1907.

*A. congensis* var. *glabrata* Hutch. & Dalz., Fl. W. Trop. Africa 2: 42. 1931.

Leaf blades closely resembling those of *A. Boonei*, more often acuminate at apex, sessiloid or sessile. Inflorescence sparsely puberulent or glabrous, generally more loosely and sparsely flowered than that of *A. Boonei*; calyx glabrous or sparsely pubescent; corolla tube 3.7–5.7 mm. long, pubescent outside; corolla lobes 4.8–7.3 mm. long and 2.5–4.7 mm. broad; anthers 1.2–1.6 mm. long; ovary glabrous or sparsely hairy. Follicles glabrous.

TYPE.—"Congo; infra Ponta da Lenha. (4.9.74.)." Dr. Naumann, from Boma district.

ILLUSTRATIONS.—Vermoesen, Man. Essences Forest. Congo Belge (1923) 16 (leafy br. and infl., fr., seeds); De Wildeman, Miss. É. Laurent. (1907) 2: t. 162 (as *A. Gilletii* var. *Laurentii*; leafy br.).

DISTRIBUTION.—West tropical Africa, the Congo Luanda, and Belgian Congo to Nigeria. Sometimes abundant; prefers humid habitat.

Congo—*Claessens* (Br); *Corbisier-Baland* 1594 (Br, K); *Dawe* 305 (Angola; K); *De-meuse* 113 (Br); *Germain* 78 (Yandjia; Br);

*Ghesquiere* 771 (Kasi; Br); *Gilbert* 54 m (Wolenge; Br); *Gillardin* 307 (Bakuba; Br, K); *Gillet* 3532 (Belg; Br), 3751 (cotype *A. Gilletii*; Br); *Laurent* (3/1/04; type *A. Gilletii* var. *Laurentii*; Br); *Lebrun* 6691 (Mushie; Br); *Leemans* 576–580 (Eala; Br); *Leontovitch* 28 (Budjala; Br); *Louis* 12128 and 12134 (Yangole; Br); *Mortehan* 848 (Dundusana; Br); *Naumann* (4/9/74; type coll. *A. congensis*; K); *Paynaert* 788 (cotype *A. Gilletii*; Br); *Sapin* (Kasai; Madibi; Br); *Vanderyst* (Balanda; Br).

South Nigeria—*Dalziel* 1256 (type *A. congensis* var. *glabrata*; K).

VERNACULAR NAMES.—Same as for *A. Boonei*.

Cotypes of *A. Gilletii*.—"Region de Kisanu, 1904 (*J. Gillet* 3531); Sanda, 1904 (leg. Oddon, coll. *J. Gillet* 3751); Eala, decembre 1906 (*L. Pynaert* 788)." The type of *A. Gilletii* var. *Laurentii*, collected by Laurent, "Bolombo, 3 janvier 1904," is of sterile material. It was distinguished from the typical plant by the fact that the leaves were more numerous in each verticil (9, as against 4–7 in the typical species). This character is too trivial for varietal segregation.

Type of *A. congensis* var. *glabrata* (Kew Bul. 1937: 337).—"S. Nigeria: Lagos Town, Oct., *Dalziel* 1256." *A. Boonei* ("*A. congensis*" of most authors and herbarium distribution) served as the basis for comparison with this plant. Hutchinson and Dalziel did not judge their plant as sufficiently different from *A. Boonei* for specific rank.

The type is sterile and was collected from a young plant ("Strauch"). When flowering specimens of African *Alstonia* were subsequently collected they were referred to this species because of the great vegetative similarity and because *A. congensis* was the only African species known at that time. This flowering material was accepted as characterizing *A. congensis*. Then *A. Gilletii* was distinguished, chiefly on basis of its strikingly different floral features. As numerous collections accumulated it became evident that two

species were involved in African *Alstonia*. These, although best distinguished by their flowers, almost always present slight differences in leaf habit, differences which are quite evident in typical collections. From a study of the vegetative features of *A. Gilletii* and the type of *A. congensis* it is concluded that the two represent one and the same species. Consequently the plants previously referred to *A. congensis* need some other name. This need is filled by *A. Boonei*.

5. *Alstonia angustiloba* Miq., Fl. Ind. Bat. 2: 438. 1856.

*A. calophylla* Miq., Fl. Ind. Bat. 2: 439. 1856.

*A. angustiloba* var.  $\beta$  *glabra* Koord. & Val., Bijdrage 1: 121. 1894.

*A. iwabigensis* Elmer, Leaflets Philip. Bot. 4: 1447. 1912.

*Paladelphina angustiloba* Pichon, in Paris Mus. d'Hist. Nat. Bul. II, 19: 299. 1947.

Trees up to 40 m. tall and 1 m. in diameter. Petioles 2–3.5 cm. long. Leaf blades elliptic, 7–23 cm. long and 3–8 cm. broad, acuminate at apex, the lateral nerves 45–100 pairs, 1–3 mm. apart, horizontal, very straight, the transverse veins often prominulous on upper side but not as prominent as those of *A. scholaris*. Inflorescence puberulent, many-flowered, the pedicels short (up to 3 mm. long), puberulent; calyx lobes ovate to lanceolate, 0.9–2.2 mm. long, obtuse or acute at apex, puberulent outside, glabrous or sparsely hairy inside, ciliate; corolla tube about 6–7 mm. long, glabrous outside; corolla lobes oblong-ligulate to almost orbicular, very faintly ciliate near apex; anthers 0.7–1 mm. long; follicles varying from densely puberulent to glabrous.

TYPE.—"*Alstonia spectabilis* herb. L. Batav. excl. syn. R. Br. Java."

ILLUSTRATIONS.—Koord. and Val., Atl. Bau-mart. Java (1916) t. 642 (leafy br. and infl., fl., fl. analysis, frs., seed, habit of tree).

DISTRIBUTION.—Malay States, Sumatra, and Java, north to Borneo and Palawan in the Philippines. Reported from rain forests and teak woods; also from limestone hills.

Malay States: *Alvin's coll.* (Malacca; Sing); *Cantley* 166 (Singapore; K); *Corner* (Johore; Sing); *Curtis* 3087 (Penang; Sing); *Derry* 138 (Malacca; Sing); *Fox's coll.* 12699 (Penang; Sing); *Griffith* (Malacca; G, K, L); *Hervey* (Malacca; K); *Holtum* (Singapore; Sing); *King's coll.* 5270 (Perak; K); *Ridley* 8090 (Singapore; Sing), 8095 (Singapore; K); *Wray* 4058 (Perak; K, Sing).

Riouw: *Neth. Ind. For. Serv.* 27574 (Mo).

Sumatra: *Achmad* 665 and 1032 (Simaloer; L), 1086 (Simaloer; K, L, Sing); *Bartlett* 7251 and 8432 (Asahan); *Boschproefst.* 515 and 598 and 831 and 919 and 4148 (Palembang; L); *Endert E.* 1065 (Benkoelen; L); *Krukoff* 204 (Kisarin; NY, US); *Neth. Ind. For. Serv.* 31968 (Palembang; A); *Teysmann* (herb. L. Bat. 994; Loeboe Aloeng; type coll. *A. calophylla*; G, K, L); *Thorenaar* 831 (Palembang; L).

Java: *Herb. Hort. Bat. Bog.* 285 (cult. IV–A–47; US); *Kollmann* (1838); *Koorders* 1 (K), 12341 (Soekaboemi; UC), 14230 (K); *Neth. Ind. For. Serv.* 3923 (Pandeglang; A).

Borneo: *Haviland* 1732 (Kuching; K, Sing); *Neth. For. Serv.* 14202 and 16068 (A), 18857 (Berouw; A); *Motley* 775 (Bangormassing; K). Brit. North Borneo: *Keith* 1271 and 1321 (Sandakan; K).

Philippines: Palawan: *Elmer* 13167 (type coll. *A. iwabigensis*; A, F, G, GH, K, L, Mo, NY, US); *Merrill* 748 (sterile; NY, US).

VERNACULAR NAMES.—British North Borneo: *Pulai*; Malay States: *Jelutong*.

Type of *A. calophylla*.—"Sumatra, bij Loeboe Aloeng (Teysm.)." Sterile, and apparently consists merely of juvenile leaves. Closely resembling the type of *A. calophylla* are *Krukoff* 204 and, less so, the *Hervey* (June 29, 1885) collection. Flowering material has not yet been directly linked with these leaf forms.

*A. angustiloba* var. *glabra* was distinguished solely by its glabrous ovary; that of the typical form being hirtellous. The ovaries of the specimens examined vary from completely glabrous to very sparsely pubescent (several hairs present) to sometimes definitely hirtellous. Because



of this intergradation and the lack of any other distinguishing feature the variety is not recognized.

Type of *A. iwahigensis*.—"13167, A. D. E. Elmer, Puerto Princesa (Mt. Pulgar), Palawan, May, 1911, Philippines. Of the species only one tree was found in fertile soil of humid forests at 750 feet alt. along the trail to Napsan on the opposite coast of the island." The inflorescence is somewhat more congested, and the calyx lobes are slightly longer and sharper at the apex than is usual for *A. angustiloba*.

The Palembang material which has been distributed under an unpublished name attributed to Backer in manuscript belongs with *A. angustiloba*.

6. *Alstonia pneumatophora* Backer ex L. G. Den Berger, in Meded. Proefst. Thee 97: 153. 1926. Ex K. Heyne, Nutt. Pl. Ned.-Ind. ed. 2, 2: 1277. 1927.

Foliis his *A. spatulatae* consimilibus et floribus his *A. angustilobae* consimilibus; folliculis furfuraceo-rubiginoso-puberulis pilis minutis crispis.

Trees up to 45 m. tall and 1 m. in diameter. Petioles 0–7 mm. long; leaf blades spatulate, rounded or slightly retuse or faintly blunt-acuminate at apex, 4–11 cm. long and 2–4.5 cm. broad, the lateral nerves 20–35 pairs, 2–4 mm. apart, often a little ascending, lightly arcuate, the transverse veins and reticulation usually obscure. Inflorescence with many crowded flowers, puberulent, the pedicels very short; flowers closely resembling those of *A. angustiloba*; calyx lobes 1.4–1.9 mm. long, puberulent outside and inside; follicles scurfy rusty-puberulent with minute crisped hairs.

LECTOTYPE.—*Boschproefst.* 28 E. 1 P. 505, Sumatra, Palembang; fl. and fr. (Leiden.)

ILLUSTRATIONS. — Meded. Proefst. Thee (1926) 97: t. 29, fig. 113 (wood anatomy).

DISTRIBUTION.—Sumatra, Borneo, and Celebes; moist habitat.

Sumatra: *Boschproefst.* 418 (Palembang; K, L, Sing), 502 (Palembang; L), 505 (type

coll.; Palembang; K, L, P), 511 and 512 (Palembang; L), 536 (Palembang; L, UC), *Grashoff* 785 (Palembang; L), *Neth. Ind. For. Serv.* 19853 (Ophir; A), 19860 (Ophir; L), 23838 (Palembang), 31007 (Tapanoeli; A), *Yates* 842 (Asahan; A).

Riouw: *Boschproefst.* 6304 (Karimon; L), 9965 (L).

Borneo: *Abubakar* 4236 (Beaufort; Sing), *Bartlett* (Sarawak; BM), *Haviland* 1689 (Sarawak; K, Sing), *Neth. For. Serv.* 16089 (L), 17783 (A).

Celebes: *Boschproefst.* Cel/111/51 (L), Cel/111/130 (A).

VERNACULAR NAMES.—Heyne reports the following: *Basoeng*, *Poelai Kapoer*, *Poelai Renah*, *Pulai Lilin* (Brunei) appears on an herbarium label.

This species has not hitherto been described taxonomically, therefore a Latin diagnosis has been included. Berger treated the wood anatomy, whereas Heyne presented some general features such as habit, habitat, pneumatophores, wood, and uses.

- 6a. *Alstonia pneumatophora* var. *petiolata* Monachino, var. nov.

A forma typica speciei petiolis elongatis usque ad 2.5 cm. longis recedit.

Differs from the typical form in its very long petioles, which are about 2 cm. long; the leaf blades are somewhat less spatulate, the lateral nerves about 23 pairs, 3–4 mm. apart.

TYPE.—*Endert* 28 E. 1 P. 537, Archipel. Ind. Sumatra, Palembang, (Leiden.)

7. *Alstonia spatulata* Blume, Bijdr. 1037. 1826.

*A. cuneata* Wall., Num. List 1645. 1829 (nom. nud.).

*A. cuneata* Wall. ex G. Don, Gen. Syst. 4: 87. 1837.

*A. cochinchinensis* Pierre ex Pitard, in Leconte and Humbert, Fl. Gen. Indo-Chine 3: 1165. 1933 (pro synon.).

Trees seldom greater than 15 m. tall (reported 30 m. or more) and 50 cm. in diameter.

Petioles 0.5–1.5 cm. long; leaf blades closely resembling those of *A. pneumatophora*. Inflorescence very loosely cymose, very sparsely flowered, the pedicels 10 (–13) mm. long; calyx lobes ovate-deltoid, 1–2 mm. long, obtuse at apex, ciliate, otherwise completely glabrous; corolla tube glabrous outside; corolla lobes 6.9–11.4 mm. long and 4–5 mm. broad, barbate at base within and very faintly ciliate near apex, otherwise glabrous; anthers 1–1.3 mm. long; ovary glabrous; follicles 3–5 mm. in diameter, glabrous.

TYPE.—"circa Rompien." Java, Blume.

ILLUSTRATIONS.—Koord. and Val., Atl. Baumart. Java. (1916) t. 643, 644 (leafy br. and infl., fls., fl. analyses, fr., seed, habit of trees); Die Umschau (1934) 38: 170, fig. 1 (photo showing a group of trees growing in water), 171, fig. 2 (photo of piece of root).

DISTRIBUTION.—French Indo-China and Siam to Sumatra, Java and Borneo. Said not to be found in eastern and middle Java. Grows in marshlands or low rich soil, often in swamps in water up to 1 m. deep.

French Indo-China: *Pierre* 4409 (Baria and Thu-dau-mot; A, NY); *Thorel* 1146 (Thu-dau-mot; A, US).

Siam: *Kerr* 15078 (Pattani; BM, K, Mo), 15612 (Pak Zing; A, BM, K); *Rabil* 255 (Trang; A, BM, K).

Malay States: *Burkill* 1296 (Selangor; UC); *Cantley* 1937 (Malacca; K); *Derry* 1064 (Malacca; Sing); *Griffith* (Malacca; K); *King's coll.* 4009 (Perak; BM, K), 7464 (Perak; L), 7780 (Perak; BM, Sing); *Maingay* 1068 (K, L), 1712, 1716 (Malacca; K); *Sing. For. F.M.S.* 1296, 1821 (Selangor; Sing), 15245, 20191 (Selangor; K), 2159 (Perak; K, Sing); *Scortechini* 1716 (Perak; G, K); *Wray* 170 bis (Perak; BM).

Sumatra: *Boschproefst.* 823 (L); *Mus. Econ. Bot.* (Palembang; L); *Endert E.* 823 (Palembang; L); *Rappard* 122 DB (Benkoelen); *Rahmat si Boeea* 8243 (Asahan; A); *Rahmat si Toroës* 1866 (vicinity of Rantau Parapat), 5219 (Tapanoeli); *Yates* 2166 (Asahan).

Bangka: *Boschproefst.* 15404 (L).

Java: *Backer* 31166 (Batavia; K); *Kollmann;* *Koorders* 40502  $\beta$  (Bantam; A); *Zollinger* 3567 (P).

Borneo: *Amdjab* 2 (K, L); *Edwards* 3890 (Brit. N. Borneo; K); *Hallier* 99; *Haviland* 1689 (Sarawak; BM), 3044 (Sarawak; Sing); *Lobbe* (K); *Neth. Ind. For. Serv.* 18115 (Koeala; A); *Polak* 461 (Ameontai; Mo); *Wood* 2601 (Brit. N. Borneo; UC).

VERNACULAR NAMES.—Siam: *Tia*; Sumatra: *Kajoe-Poele*, *Kajoe Gaboeh*, *Poelai*; Sunda Area: *Gabusan*, *Lane Bodas*; British North Borneo: *Pulai Paya*, *Tambailik*.

Type of *A. cuneata*.—"Native of Sirmore, where it was collected by Dr. Gowan. *Wall. cat. no. 1645*." Sirmur, in Punjab, is the wrong locality, as pointed out by Hooker and King and Gamble. The name is placed in synonymy of *A. spatulata* by these authors and others. The sparsely flowered inflorescence ("peduncle 3-flowered?") and the shape of the whorled leaves ("obovate, retuse at top") described for *A. cuneata* point to *A. spatulata*.

8. *Alstonia actinophylla* (A. Cunn.) K. Schum., in Engl. and Prantl, *Natürl. Pflanzenfam.* 4 (2): 138. 1895.

*Alyxia actinophylla* A. Cunn., in *Bot. Mag.* 61 (new ser. 8): 3313. 1834.

*Alstonia verticillosa* F. v. Muell., *Fragm.* 6: 116. 1868.

Trees up to 20 m. or more tall; branches slender. Petioles about 1 cm. long. Leaf blade elliptic or sub lanceolate, 5–12 cm. long, 1–3 cm. broad, narrowed or sometimes short-acuminate at apex, the margins unrolled, the lateral nerves 35–50 pairs, about 2 mm. apart, the transverse veins more or less prominulous. Inflorescence loosely cymose, many-flowered, glabrous, the pedicels slender, distinct, up to 4 mm. long, glabrous; calyx lobes broadly ovate, about 1–1.5 mm. long, rounded or obtuse at apex, ciliate, puberulent with adpressed hairs inside, otherwise glabrous; corolla tube about 8 mm. long, glabrous outside; corolla lobes 4–5 mm. long, barbate at base within and very sparsely ciliate toward apex, otherwise glabrous; anthers



dehiscing almost to base; follicles glabrous; seed faintly muricate-roughened.

COTYPES CITED.—"Hab. in Australasia, ad oras tropicas; nempe Endeavour River, supra littus orientale, necnon littora septentrionali-occidentalia, Montagu Sound, etc. 1820 *A. Cunningham*. (v.v.)."

LECTOTYPE.—*Cunningham* 206, Australia, Montague Sound (Gray Herbarium).

ILLUSTRATIONS.—Schimper, *Pflanzen-Geogr.* (1898) 353 (as "*A. verticillata*"; br. and petioles only).

DISTRIBUTION.—Northern Australia and southern New Guinea. Often common in tropical scrub, rain forests, and savannas.

Australia: Queensland: *Bailey* 148 (Hammond Island; Bri); *Cowley* 13 (Cooktown; Bri); *Cunningham* 378 (cotype coll. *Alyxia actinophylla*; Endeavour Rv.; K); *Daemel* (Cape York Penins.; K); *Hill* 67 (Albany Is.; K); *Norton* (Cooktown; Bri); *Persich* 31 (Endeavour Rv.; Bri); *Thurston* 3996 (Bri); *Whitehouse* (Cape York Penins.; Bri). Northern Territory: *Armstrong* 372 (Port Essington; K); *Mueller* (Roper Rv.; K); *Schultz* (Port Darwin; K). Western Australia: *Cunningham* 206 (cotype coll. *Alyxia actinophylla*; Montague Sound; GH, K).

New Guinea: Papua: *Brass* 8282 (Gaima; A), 7940 (Lake Daviumbu; A). Netherlands New Guinea: *Koch* (Merauke; L), *Versteeg* 279 (Merauke; L).

Type of *A. verticillosa*.—"Ad promontorium Cape York; Daemel."

### § BLABEROPUS

Shrubs about 8 m. or less tall, sometimes dwarf. Glands at axils of leaves numerous, deltoid to linear, up to 3 mm. long; pedicels distinct, long, 5–15 mm. long. Calyx about 2 mm. diam., glabrous or sparsely pubescent outside like the inflorescence, the lobes ovate to ovate-lanceolate, acute or sometimes obtuse at apex, about 1–2 mm. long (lanceolate-acuminate and up to 3.5 mm. long in *A. yunnanensis*), margins thin; corolla glabrous

outside (some scattered hairs present in *A. yunnanensis*); anthers dehiscing their entire lengths; ovary superior, glabrous, the disc with lobes 0.7–2 mm. long, varying in length; style long and slender; stigma-apiculi about 0.5 mm. or less long; follicles short, about 15 cm. or less long, glabrous; seeds about 7–11 mm. long and 2–4 mm. broad, thin, the surface minutely foveolate and smooth (seeds rather thick and muricate in *A. yunnanensis*), the cilia about 0.5–1 cm. long.

The species in this section are known from India to China and Java. In general they prefer high altitudes, and are rare and localized. Specimens are poorly represented in herbaria, and are generally very difficult to distinguish; fruits as well as flowers are important for precise identification.

9. *Alstonia venenata* R. Br., in Mem. Wern. Soc. 1: 77. 1811.

*Ecbites venenata* Roxb., Hort. Beng. 20. 1814.—nom. nud.

*Blaberopus venenatus* A. DC., Prod. 8: 411. 1844.

Shrubs 2–3 (–7) m. tall. Petioles 1–2.5 cm. long, leaf blades more or less elliptic, usually broadest slightly above the middle, 6–22 cm. long and 2–5.5 cm. broad, the lateral nerves 70–100 pairs, 1–3 mm. apart. Calyx lobes ciliate, otherwise glabrous; corolla tube 2–3 cm. long; corolla lobes 1–2 cm. long; anthers 1.8–2.5 mm. long; lobes of disc linear-lanceolate, 1.5–2 mm. long; stigma-apiculi very short and blunt; follicles 6–13 cm. long and 6–7 mm. diam., the slender stipes 1.5–3 cm. long.

TYPE.—"India Orientali, Gul. Roxburgh, M. D. (v.s. in Herb. Banks)."

ILLUSTRATIONS.—Lodd Bot. Cab. (1826) 12: t. 1180 (veg., fls.); Wight, Illustr. Ind. Bot. (1850) 2: t. 154–6, E (as *A. scholaris*; fl. analysis, seed, embryo; obviously § *Blaberopus*, prob. *A. venenata*); Wight, Ic. Pl. Ind. Or. (1843) 2: t. 436 (veg., fls., frs.; follicles better represent those of *A. neriifolia*, as they are not stipitate).

DISTRIBUTION.—Native to India; probably

also in Burma.

India: *Anglade* (Pulney Hills; fl.; A), 25 (Pulney Hills; fl. and fr.; G); *Anstead* 13 (Travancore; fl.; A); *Bourne* (Madras; fl. and fr.; K) (Kodaikanal Ghat; fl.; K); *Gamble* 11421, 14320 (Nilgiri; fl.; K); *Hohenacker* 1385 (Nilgiri; fl. and fr.; G); *Roxburgh* (fl.; BM); *Stocks et al.* (Konkan; fl. and fr.; Bri, K, NY); *Talbot* 793 (Kanara; fl. and fr.; K); *Thomson* (Madras; fl., fr.; G, GH, K); *Wallich* 1647 (fl. and fr.; K), 1647  $\beta$  (Hort. Bot. Cal.; fl. and fr.; G); *Wight* 1871 (Nilgiri; fl.; K), 1871 *bis* (Courtallum; fl. and fr.; G, K, NY, Sing, UC).

Burma: *Parkinson* 6152 (Northern Shan States, Gokteik Gorge; fl.; fr. necessary to distinguish with certainty from *A. neriifolia* var. *glabra*; K).

Malay Peninsula: Singapore: *Lobb* (loc.?; fl.; K).

Australia: Queensland: *C. T. White* 8640 (Brisbane; cult.; fl.; A, Bri).

United States: California: *Waltier* (Santa Barbara; cult.; fl.; A).

West Indies: Barbados: *Waby* 127 (Hastings; cult.; fl.; F).

*Echites venenata* was published by Roxburgh without reference to Brown's species. The plant was noted to be called "Ganda-ganeroo" in the Tailand language and to have been donated by C. Campbell in 1805.

H. H. Haines (1922:540) states regarding this species "Leaves . . . softly hairy beneath but more or less glabrescent with age."

9a. *Alstonia venenata* var. *pubescens* Monachino, var. nov.

A forma typica speciei foliis inflorescentiisque pubescentibus recedit.

TYPE.—*J. S. Gamble* 13973, India, Madras, Ganjam District, W. Sarada, about 300 m. altitude; 1884; fruiting specimen. (Kew.)

DISTRIBUTION.—Grows together with the typical form.

India: *Gamble* 13973 (type), 15905 (Madras, Godavari; fr.; K); *H. H. Haines* 3366 (Central Prov., Chanda; fl.; K), 4043 (Orissa,

Angul; fr.; K), 4876 (Orissa, Bonai; fr.; K); *Wight* 1871 (fr.; mixed with typical *A. venenata* in flower; GH).

10. *Alstonia neriifolia* D. Don, Prod. Fl. Nep. 131. 1825.

*Alstonia sericea* Blume, Bijdr. 1038. 1826.  
*Blaberopus neriifolius* A. DC., Prod. 8: 411. 1844.

*Blaberopus sericeus* A. DC., Prod. 8: 411. 1844.

Very closely resembling *A. venenata* var. *pubescens* except for the fruits; glands at leaf axil generally longer than in *A. venenata*, up to 3 mm. long; corolla tube shorter, usually less than 20 mm. long; lobes of disc usually shorter, 0.7–1.5 mm. long, sometimes with faint teeth at either side near base.

TYPE.—"Hab. in Nepalia. *Wallich*," Num. List. 1646.

ILLUSTRATIONS.—Horticulteur Univ. (1845) 6: 37 (as *Blaberopus sericeus*; leafy br. and infl., fl. analysis; plant said to have been brought by Neumann from Madagascar in 1824 and cultivated for a long time at Paris).

DISTRIBUTION.—India, occasionally cultivated but native probably only north in the tropical Himalayan region; the identical species, or one very closely resembling it, is also found in Java.

India: *Calcut. Hort. Bot.* (fl. and fr.; G, K); *Dalzell* (Bombay; cult.; fl. and fr.; K); *Griffith* (fl. and fr.; K); *Helper* 23; *Hooker* (Nepal; GH, K); *Pierre* 5236 (cult.; P); *Wallich* 1646 (fl.; K), 1646 B (fr.; G, K).

Ceylon: *Thomson* (1845; cult.; fr.; K).

Malay Peninsula: *Dalhousie* (Penang; fl.; K).

Java: *Blume* (fl.); *Kollmann* (1838; fl.); *Zollinger* 1158 (1844; fl.; G).

Réunion: *Bernier* (cult.; fl. and fr.; K).

Mauritius: *Blackburn* (cult.; fl.).

Type of *A. sericea*.—"montosis Salak," Java, Blume.

The Java specimens which have been examined have corolla tubes slightly longer (17–20 mm.) than those from India (12–19 mm.).



The data appearing on the labels of the herbarium material are poor; perhaps some of the Indian collections with longer corollas are from cultivated plants originally derived from Java, thereby confusing the true picture of morphological elements present in the native Indian specimens. If *A. neriifolia* from the Himalayas and *A. sericea* from Java are truly identical, the geographical distribution of the species is anomalous. There are indications that Himalayan elements sometimes extend to western Java in a discontinuous fashion, but such a distribution in *A. neriifolia* would display a habit contrary to that of *B. Blaberopus*, which is noteworthy for localization of its species. However, with the specimens now at hand there is no alternative but to consider *A. neriifolia* and *A. sericea* conspecific.

10a. *Alstonia neriifolia* var. *glabra* Monachino, var. nov.

A forma typica speciei foliis inflorescentiisque glabris recedit.

TYPE.—J. S. Gamble 7574, Northeast India, Sikkim, Darjeeling; Dec. 1879; fruiting. (Kew.)

DISTRIBUTION.—India: Gamble 7574 (type). United States: Florida: *For. Pl. Intr.* 65248 (Chapman Field, ex Darjeeling; cult.; fl. and fr.; US).

11. *Alstonia Sebusi* (van Heurck & Muell. Arg.) Monachino, comb. nov.

*Blaberopus Sebusi* van Heurck & Muell. Arg., in van Heurck, *Obs. Bot.* 2: 188. 1871.

Leaves and fruits as in *A. venenata* var. *pubescens*. Differs in the flowers; corolla tube about 1 cm. long; corolla lobes about as broad as long, very short, about 2 mm. long, the margins rumpled and inrolled; stigma-apiculi sharp.

TYPE.—"India orientali: Griffith 2343. (In hb. van Heurck.)."

DISTRIBUTION.—Himalayas; apparently rare.

Bhutan: R. E. Cooper per A. K. Bulley (7/9/14; fr.; BM); Griffith 2343 (type coll.; fl. and fr.; K).

The type collection of *Blaberopus Sebusi* consists of an infrutescence disjointed from a leafy branch with flowers. These were examined by Bentham, who decided that the species was a mixture, the fruits being of *A. venenata* and the flowers of *A. neriifolia*. The species thenceforth fell into discredit and has not been recognized until now.

There is no justification for believing that the type of *B. Sebusi* is a mixture. A careful examination of the type of indumentum and other individual features in the calyces and pedicels of the fruiting and the flowering material proves almost with certainty that the two parts belong to the same collection. Furthermore, the flowers are not of *A. neriifolia* but of a distinctive element. The discovery in Yunnan of a variety in which the *A. venenata* kind of fruits is associated with the same distinctive flowers found in the type of *B. Sebusi*, is additional proof.

Only a single specimen of flowering material has been examined in the species, and here the flowers are not fully matured. The stigma-apiculi are about 0.5 mm. long and the anthers 1.6 mm. long.

11a. *Alstonia Sebusi* var. *szemaoensis* Monachino, var. nov.

A forma typica speciei foliis inflorescentiisque glabris recedit.

TYPE.—A. Henry 11932, China, Yunnan, Szemao, w. mts., about 1500 m. (Kew, presented by Dr. A. Henry in 1898.)

Yunnan: Szemao: A. Henry 11932 (type; fl.; K), 13244 (fr.; A, K, US).

12. *Alstonia Mairei* Léveillé, Cat. Pl. Yun-Nan 9. 1915.

*Wikstroemia Hemsleyana* Léveillé, in *Bul. Geog. Bot.* 25: 41. 1915.

*Alstonia paupera* Hand.-Mazt., in *Anz. Akad. Wiss. Wien.* 57: 241. 1920.

Petioles about 1 cm. long; leaf blades resembling those of *A. venenata* but usually smaller, 5–10 cm. long and 1–2 cm. broad, oblanceolate, glabrous, the lateral nerves 30–40

pairs, 1–2 mm. apart. Inflorescence like that of *A. venenata*, somewhat more crowded, glabrous; calyx lobes 1.2–1.8 mm. long, not ciliate; corolla like that of *A. venenata*, the tube about 2 cm. long, the lobes 1 cm. long; anthers 2.2–2.6 mm. long; stigma-apiculi very small; follicles 4–7 cm. long; cilia of seeds white.

TYPE.—“Rochers de Kiang-ti, 2,300 m. juill., 1912 (*E. E. Maire*).” In Cat. Pl. Yun-Nan 279, under “Additions et Corrections,” Lévillé places *A. Mairei* in synonymy of *A. venenata*, but the two are amply distinct.

ILLUSTRATIONS.—Sunyatsenia (1934) 2: t. 21 (as *A. paupera*; leafy br. and infl., fl., fr., pistil).

DISTRIBUTION.—China: Yunnan and Szechwan; in arid soils at high altitudes.

Yunnan: *Handel-Mazzetti* 696 (type of *A. paupera*; photo of fruiting specimen only; A); *Maire* (portion of type; A); *Maire* (cotype *Wikstroemia Hemsleyana*; A).

Szechwan: *T. T. Yü* 1344 (Hai-Chang Hsien; fl. and fr.; A).

Cotypes of *Wikstroemia Hemsleyana*.—“Yun-Nan: rochers de Ta Tchai 500 m.; rochers derrière Kiao-Kiao 450 M., montagnes de Mo-Tsou, 800 m., avril-juillet 1911, 1912 (*E. E. Maire*).”

Type of *A. paupera*.—“Prov. Yünnan: Eiusdem ditionis im rupestribus aridis infra vicum Tschenminte ca. 1300 m, legi 18. III. 1914.” The label of the type gives the collection number 696 and has the following data: “In faucium fluvii Djinscha-djiang (“Yangste-kiang”) ad viam directam inter Yünnanfu et Huili regione subtropica, in valle torrentis inter vicos Homöndschang et Bödschagwan. Substr. conglomerato rupium; alt. s. m. ca. 1550 m.” Tsiang (1936: 139) places the species in synonymy of *A. Mairei*; he does not indicate whether he examined the type.

### 13. *Alstonia Curtisii* King & Gamble, in Jour.

As. Soc. Beng. 74 (2): 439. 1907.

Closely resembling *A. Mairei*; lateral nerves of leaf blades 35–50 pairs; inflorescence more sparsely flowered than that of *A. Mairei*; calyx

lobes not ciliate; corolla tube about 3 cm. long, inflated at about one-fourth below mouth and characteristically constricted at throat for a length of about 5 mm.; anthers about 2.8 mm. long, their tips reaching 5–6 mm. below mouth.

TYPE.—“Kasoom: limestone islands, *Curtis* 3242.”

DISTRIBUTION.—Malay Peninsula: Lower Siam: *Curtis* 3242 (type coll.; fl. and fr.; K, Sing).

### 14. *Alstonia rupestris* Kerr, in Kew Bul. 1937: 43. 1937.

*Blaberopus rupester* Pichon, in Bul. Mus. d'Hist. Nat., Paris, II, 19: 300. 1947.

Leaves closely resembling those of *A. Curtisii* but sessile. Inflorescence rather crowded, the pedicels comparatively short (up to about 3 mm. long); calyx lobes not ciliate; corolla tubes about 7–8 mm. long; corolla lobes 2.5 mm. long; anthers 1.4 mm. long (only buds seen); lobes of gland almost as broad and as long as the ovary; cilia of seeds brown.

TYPE.—“Doi Chiangdao, c. 1800 m., on limestone rocks in open evergreen forest, *Kerr* 5560 (type), *Put* 366.”

Siam: *Kerr* 5560 (type coll.; fl.; BM, K); *Put* 366 (fr.; A, BM).

### 15. *Alstonia yunnanensis* Diels, in Bot. Gard. Edin., Notes 5: 165. 1912.

*Alstonia Esquirolii* Lévillé, Cat. Pl. Yun-Nan 10. 1915.

*Acronychia Esquirolii* Lévillé, Fl. Kouy-Tcheou 374. 1915.

Shrubs 1–3 m. tall. Petioles very short or none. Leaf blades lanceolate, 7–18 cm. long and 2.5–4 cm. broad, hispidulous-pubescent beneath (at least along nerves); lateral nerves comparatively few and distantly spaced, 20–30 pairs, 2–5 mm. apart. Inflorescence short-peduncled (peduncles 0.5–1 cm. long), small, about 2 cm. long and about as broad, sparsely flowered, hispidulous, the pedicels up to 8 mm. long; calyx lobes long linear-acuminate from an ovate base, acute at apex, ciliate, otherwise glabrous or nearly so; corolla tube about 1 cm.



long, glabrous outside or with some scattered hairs on upper part; corolla lobes 3–6 mm. long and 2–3 mm. broad, acute at apex, ciliate; anthers 2–2.2 mm. long; stigma-apiculi about 0.5 mm. long; lobes of disc about length of ovary, 1.5 mm. long; follicles about 3–4 cm. long, sometimes lightly constricted at intervals. Seeds comparatively very thick (about 0.6 mm. thick), strongly and closely muricate, the cilia very pale brown.

TYPE.—“In woods on hills west of Yunnanfu. Alt. 7–8000 ft. Feb. 1905. *G. Forrest* 592. (From about the same locality also *Ducloux*, 20th Apr. 1904.)”

DISTRIBUTION.—China, Yunnan, and Kweichow; high altitude (reported from 1,600 m. to 2,000 m., rocky places, mountain slopes).

Yunnan.—*Maire* 138 and 395 (Mi Tsao; A); *Henry* 9779 (Meng Tzi Mts.; A, NY, US), 13244a (Szemao; A, Mo, NY); *Handel-Mazzetti* 6089 (near Yunnan Fu; A); *Forrest* 16177 (A), 9930 (Koia Kuan Valley; BM, K, UC); *McLarren* C. 173 (K); *Tsiang and Wang* 16323 (Ta-p'o-chi, Kun-Ming; A); *Wang* 72241 (Chen Kang Hsien; A), 62906 (Kun-Ming; A).

Kweichow.—*Esquirol* 740 (type coll. *A. Esquirolii*; fl.; A); *Tsiang* 8508.

Type of *Alstonia Esquirolii*.—“Kouy-tchéou, août 1905 (*Jos. Esquirol* 740).”

Type of *Acronychia Esquirolii* (fide Rehder).—“China. Kweichow: ruisseau derrière Bo-ly et chemin de Kéou-tin, *J. Esquirol* 3212, June, 1911.” Examined by Rehder (1934: 315) and Tsiang (1936: 138), who place it in synonymy of *Alstonia yunnanensis*.

### § MONURASPERMUM

Trees, sometimes 20–25 m. tall. Leaf blades more or less acuminate at apex, usually varying from completely glabrous to densely pubescent beneath, the lateral nerves usually 15–20 pairs, 5–10 mm. apart. Calyx lobes pubescent or at least ciliate; corolla tube 3–6 mm. long, the lobes bearded at base within with linear or clavate hairs; anthers 0.6–1.3 mm. long, located at middle or up to throat of corolla tube. Fol-

licles long; seeds brown, 5–9 mm. long and 1–2 mm. broad, the cilia silky-maroon, variable in length, 5–18 mm. long; cotyledons narrow.

The leaves and fruits are often very similar in different species; flowers are necessary for precise identification.

Siam to the Solomon Islands; often common.

16. *Alstonia angustifolia* Wall. ex. A. DC., Prodr. 8: 409. 1844.

*A. angustifolia* Wall., Num. List n. 1650. 1829.

*Amblyocalyx Beccarii* Benth. in Hook., Ic. Pl. 12 (3d ser. 2): t. 1179. 1876.

? *Alstonia angustifolia* var. *elliptica* King & Gamble, in Jour. As. Soc. Beng. 74 (2): 441. 1907.

*A. Beccarii* Pichon, in Paris Mus. d'Hist. Nat. Bul. II, 19: 297. 1947.

Trees up to 20 m. tall. Petioles 1–2 cm. long; leaf blades 8–19 cm. long and 2–6 cm. broad, the lateral nerves about 15 pairs, 8–12 mm. apart. Inflorescence with branches and pedicels divaricate, closely pubescent; calyx tube about 1.2–1.3 mm. long, about 2 mm. or less broad; calyx lobes very densely tomentose outside and inside, usually spreading or reflexed; corolla tube 3–3.5 mm. long, densely tomentose outside; corolla lobes broadly rounded, 1.2–2.5 mm. long and 1.4–2.2 mm. broad, densely tomentose outside and inside; stamens inserted slightly above middle of corolla tube.

TYPE.—“*Wall. list* 1650. Singapore,” 1822.

ILLUSTRATIONS.—Hook., Ic. Pl. (1876) 12: t. 1179 (as *Amblyocalyx Beccarii*; leafy br. and infl., fl., fl. analysis; representation of ovules as 2 per cell suspended from near apex is erroneous).

DISTRIBUTION.—Malay Peninsula, where frequent in the southern states, to Sumatra, Bangka, and Borneo; usually in moist places at low altitudes.

Malay States.—*Alvins* 668 (Malacca; Sing); *Corner* 21307 and 31452 (Johore; Sing); *Derry* 1080 (Malacca; Sing); *Maingay* 1066 (Penang; fl.; mixed with var. *latifolia*; GH, L); *Ridley*

10942 (Johore; Sing); *Sing. Field no. 34057* (Selangor; A); *C. Smith 18151* (Selangor; Sing).

Singapore.—*Anderson 140* (BM, K, L); *Baker 5660* (G); *Corner* (Sing); *Cantley 2789* (Sing); *Goodenough 2714* and *2716* (Sing); *Maingay 1070* (L); *Ridley 14138* (Sing), *2714* (L), *2716* (K), *2834* (BM, L, Sing), *6706* (Sing); *Wallich 1650* (1822; type coll.; fl.; G, K).

Sumatra.—Palembang: *Dumas 1533* (fl.; L); *Grashoff 974* (fl.; L).

Bangka.—*Grashoff 50* (fl.; L).

Borneo.—*Beccari 1628* (type coll. *Amblyocalyx Beccarii*; fl.; K), *3207* (Sarawak; fl.; K); *Boschproefst. 6320* (Mempawa; L); *Hallier 1622*, *B.2559* (Semitau); *Haviland 2064* (Sarawak; K, L, Sing), *2093* (Sarawak; BM, L, Sing); *Mjoberg* (Sarawak).

Type of *Amblyocalyx Beccarii*.—"Sarawak, Borneo, *Beccari 1628*."

Type of *A. angustifolia* var. *elliptica*.—"Penang: *Curtis*." King and Gamble write "Scarcely a variety, but the shape of the leaves is very distinct . . . elliptic . . . 3 to 4 in. long, 1.25 to 1.75 in. broad." Ridley (1923: 347) places the variety in synonymy of *A. latifolia*.

A. Guillaumin (1943: 55) writes that "*Alstonia angustifolia* (? *Parsonia angustifolia*)" truly exists in New Caledonia. It is very likely that his crediting *A. angustifolia* to New Caledonia is due to some confusion. The original description of *Parsonia angustifolia* Baillon does not suggest *Alstonia*.

16a. *Alstonia angustifolia* var. *annamensis*  
Monachino, var. nov.

A forma typica speciei tubo calycis brevissimo et corollis brevioribus (tubo 2.3–2.6 mm. longo) extus minus pubescentibus recedit.

TYPE.—*Poilane 5970*, Indo-China, Annam, prov. Phan Rang, Cana; received at herb. Paris in June, 1923. (Arnold Arboretum.)

Annam.—*Poilane 5970* (type; A, P), *6784* (massif de la Mère et l'Enfant) (fl.; A, NY), *10142* (Phan Rang; fl.; P).

VERNACULAR NAME.—Annam: *Cây lác*.

16b. *Alstonia angustifolia* var. *latifolia* King & Gamble, in *Jour. As. Soc. Beng.* 74 (2): 441. 1907.

*A. latifolia* Ridley, *Fl. Mal. Penins.* 2: 347. 1923.

Petioles about 2.5 cm. long; leaf blades usually 6.5–8 cm. broad. Calyx lobes hardly spreading, sharper at apex than those of the typical form; corolla tube 4.5–5.5 mm. long; anthers 1–1.3 mm. long.

Cotypes cited: "Penang: *Maingay* (K.D.) *1070/1*, *1070/2*; *Curtis 2491*; *Fox 80*; *Ridley 9306*; *Stoliczka*; *King's Collector 1341*."

LECTOTYPE.—*A. C. Maingay 1070/1*, Malay States, Penang; flowering.

DISTRIBUTION.—Malaya (principally in Penang) and the east coast of Sumatra.

Malay States.—Penang: *Corner 32451* (Sing); *Curtis 2491* (fl.; BM, Sing); *King's coll. 1637* (fr.; Sing); *Maingay 1070/1* (type; L); *Ridley 9356* (fl.; Sing); *Symington 28042* (fr.; Sing).

Malacca.—*Ridley 3189* (fr.; Sing).

Sumatra.—*Boschproefst. 2917* (Simeloen-  
goen; fl.; L); *3843* (Silindoeng; fl.; L); *Rahmat Si Boeea 8534* (vicinity of Toemoean Dolok; fl.; A).

Ridley states that *A. angustifolia* var. *latifolia* is highly distinctive. In elevating the variety to specific rank he placed *A. angustifolia* var. *elliptica* in synonymy. Specimens cited by him: "Penang Hill (Maingay and others)."

This variety seems transitional to *A. spectabilis*.

17. *Alstonia parvifolia* Merrill in Philippine  
Bur. Gov. Lab. 35: 59. 1905.

Leaves and inflorescence like those of *A. angustifolia*; pedicels up to 4 mm. long; calyx more than 3–3.5 mm. long and about 2.5 mm. broad, the calyx tube 1.2–2.9 mm. long and 2.2–3.2 mm. broad, the calyx lobes densely tomentose outside and inside; corolla tube 4–4.7 mm. long, varying from glabrous to densely pubescent outside; corolla lobes oblong, (2.5–) 3.7–4.1 mm. long and 1.4–2.9 mm. broad, varying from glabrescent to sparsely pubescent,



usually streaked with brown; stamens inserted slightly above middle of corolla tube; anthers 0.7–1.3 mm. long.

TYPE.—"Type specimen: Mount Mariveles, Province of Bataan, Luzon (2209 Meyer), Nov. 1904 (flower). From the same locality: (6876 Elmer) Nov. 1904 (fl.); (1164 Whitford) Mar. 1905 (fr.)."

DISTRIBUTION.—Philippines (principally in Luzon); a transitional form in northeast Borneo.

Philippines.—Luzon: *Borden* 24037; *Clemens* 51889 (A); *Elmer* 6876 (G, NY, K); *Loher* 6512 (K), 12551 (UC), 13498 (A); *Meyer* 27198 (*For. Bur.* 2209; type coll.; K, NY, US); *Ramos* (*Bur. Sci.* 26985); *Ramos and Edano* (*Bur. Sci.* 48553); *Whitford* 1164 (K, NY, US). Negros: *Elmer* 9690 (fl.; A, F, G, K, L, Mo, NY, L).

British North Borneo.—Mt. Kinabalu: *J. and M. S. Clemens* 28673 (A), 28673a (A, G, L, UC).

This species clearly displays affinity to *A. angustifolia*. The specimens from Borneo have their corolla lobes more pubescent within and more markedly ciliate on the margins, and are not streaked. They are transitional to *A. angustifolia*.

18. *Alstonia spectabilis* R. Br., in *Mem. Wern. Soc.* 1: 76. 1811.

*A. villosa* Blume, *Bijdr. Fl. Ned. Ind.* 16: 1038. 1826. Non Seem., *Fl. Vit.* 161. 1866.

*Blaberopus villosus* Miq., *Fl. Ind. Bat.* 2: 440. 1856.

*B. villosus* var.  $\beta$  *petiolata* Miq., *Fl. Ind. Bat.* 2: 440. 1856.

? *Alstonia longissima* F. v. Muell., *Papuan Plants* 91. 1877.

*A. villosa* var.  $\beta$  *glabra* Koord. & Val., in *Mededeel. Uit 'sLands Pl.* 11 (*Bijdrage* 1): 123. 1894.

*A. somersetensis* F. M. Bailey, in *Queensl. Agric. Jour.* 1: 229. 1897.

? *A. villosa* forma *calvescens* Markgraf, in *Bot. Jahrb.* 61: 178. 1927.

Trees up to 40 m. tall. Leaves resembling those of *A. macrophylla*, usually 3-verticillate; petioles 0–2 cm. long; leaf blades 10–30 cm. long and 2.5–9 cm. broad, varying from glabrous to densely villose beneath, the lateral nerves 18–25 pairs, 6–12 mm. apart. Ultimate branches and pedicels of inflorescence usually ascending, not divaricate; the pedicels short, less than 3 mm. long; calyx lobes variable in size, 0.9–2.5 mm. long, tomentose outside, essentially glabrous inside; corolla tube 3–3.6 mm. long, tomentose outside; corolla lobes ovate to orbicular, 1.5–3 mm. long, pubescent outside and inside; stamens inserted at about  $\frac{1}{4}$  from throat of corolla tube, the anthers 0.9–1.3 mm. long.

TYPE.—"insula Timor prope Coepang, cum floribus fructibusque Aprili 1803 Observavi . . . Praecedenti [*A. scholaris*] quam maxime affinis, sed revera distincta, nec male ab icone cit. Rumphii repraesentata." Type material was not located at the British Museum. Although the interpretation of the species rests principally on the Timor collections cited, there is little doubt that Brown's plant is here correctly placed. *A. scholaris* is also found on Timor, but Brown's comments and description ("foliis quaternis elliptico-oblongis sub-acuminatis costatis: margina simplicibus . . .") definitely preclude confusion of the two. Although there is no record of *A. macrophylla* in Timor, judging by the distribution-range this species or a variety might be expected there; in any case, the inflorescence habit and flowers of *A. macrophylla* are so strikingly different from *A. spectabilis* and *A. scholaris* that there need be no fear of its being the original species Brown had in mind. The only other known species that conceivably might be involved is *A. angustiloba*, which is known from Java; this species is very similar to *A. scholaris* and is excluded for like reasons. Brown states that the illustration in Rumphius (1741: t. 82) is not a bad representation of *A. spectabilis*. The leaf blades pictured, their shape and acute apex, their few (12–15 pairs) lateral nerves, which are dis-

tant and arcuate entirely unlike those of *A. scholaris* and *A. angustiloba*, are assuredly good for *A. spectabilis* whether or not they actually represent that species.

ILLUSTRATIONS.—Koord. and Val., Atl. Baumart. Java (1916) t. 641 (as *A. villosa*; veg., infl., fr., seed, habit of tree). F. M. Bailey, Compr. Cat. Queensl. Pl. (1913) 324 (as *A. somersetensis*; veg., infl., fr., seed). Meded. Proefst. Thee (1926) 97: t. 29, fig. 114 (as *A. villosa*; wood anatomy).

DISTRIBUTION.—Second only to *A. scholaris* in amplitude of distribution range; Java and the islands of the Javanese Archipelago, Celebes, the Moluccas, north to the Philippines (Mindanao), east to New Guinea and the Solomon Islands, and south to Queensland. Often common in rain forests of low altitudes (reported up to 450 m.).

Java.—Beumee A327 (Batavia; L); Blume 1006 (type coll. *A. villosa*; L); Elbert 355 (Madioen; L); Hallier f. 46 (cult., IV-A-82; L), 47 (Hort. Bog. ex Timor; L); Horsfield (type coll. *Blaberopus villosus* var. *petiolata*; K); Koorders 83 (K), 87 and 88 (L), 90 (Besoeiki; L), 93 (K), 97 (L), 12302 (Preanger; K, L, UC), 12333 and 13071 (L), 13372 (Pekalongan; L), 14237 (Pekalongan; L, P), 15710 (Preanger; K, L), 27296 (K), 28203 (Semarang; L), 30222 (K, L), 34148 (Semarang; L), 36884 (Pekalongan; L), 38895 (Besoeiki; L); Merrill (Buitenz. Gd.).

Kangean.—Backer 27816, 27966 and 28154 (L), 28958 (Sepandjang; K, L).

Lombok.—de Voogd 2062 (A).

Soemba.—Iboet 9 (Bri, K, L), 266 and 484 (L); Boschproefst. 15141 (L).

Timor.—*A. Cunningham* 334 (BM, K, L); *Neth. Ind. For. Serv.* 27137 (Mo); *Ex Herb. Mus. Paris* (1827; fl.; G, K, L, NY, P, US); *Riedel* (Com. A. Billeger; fl.; K).

Tanimbar.—*Neth. Ind. For. Serv.* 24391 (A).

Aroe.—*Neth. Ind. For. Serv.* 25351 and 25411 (A).

Kai.—*Jensen* 412 (L).

Celebes.—*Boschproefst.* 44 (L), 458 (K, L, Sing), 3685 and 5849 (L); *Neth. Ind. For. Serv.* 210 and 22984 (A).

Philippines.—Mindanao: *Clemens* 696 (fl.; G, F, US); *Elmer* 10840 (fl.).

Papua.—*Brass* 507 (Kappa Kappa; A), 1632 (Sandbank Bay; A), 3643; *Burke* 296 (coll.?; between s. coast of Owen Stanley Range; K); *Carr* 11399 (Hisiu); *D'Albert* (type *A. longissima*, photo only; det.?); *Lane-Pool* 103 (Buna; Bri); *C. T. White* 13 (Port Moresby; K), 16 (Post Moresby; Bri).

Australia.—Queensland: *F. L. Jardine* (type coll. *A. somersetensis*; Sept. 1897; fl.; Bri, K).

Thursday Island.—*Vidgen* 143 (1 leaf only; Bri).

Northeast New Guinea.—*Dadswell et al.* (*N.G.F.* 1741; Lae; Bri; det.?); *Waterhouse* 371 (Kabakada, north coast of Gazelle Pen.).

Solomon Islands.—Bougainville: *Kajewski* 1834 (A); *N.G.F.* 579 (Bri); *Waterhouse* 78 (fl.; K, NY, US), 341 (fl.). Guadalcanal: *Kajewski* 2449 (A); *Walker* (*B.S.I.P.* 8; Bri); *C. T. White* (*B.S.I.P.* 50; Bri). Banika: *Stoddard* 33 (A). San Christoval: *Brass* 3014 (A).

VERNACULAR NAMES.—Java: *Baloeng*, *Ilalilat*, *Langkerang*, *Legarang*; Timor: *Polé*; Papua: *Oli*; Bougainville: *Melu*; Guadalcanal: *Vulei-Kuku*.

Type of *A. villosa*.—"Monticulos calcareos Kuripan," Blume. The type specimen has very large, sessile, densely pubescent leaves, whereas the Timor plant has small, petioled, glabrous leaves; but the many excellent series of collections from Java link the two forms with numerous intermediates. The varieties proposed reflect this intergradation. It has not been feasible for me at the present time to recognize even varieties in this polymorphic species; sight is not lost, however, of the possibility that field studies may eventually define several subspecific entities. The Java specimens, in general, have hairy leaves which are shorter petioled and larger than the Timor form.

Type of *Blaberopus villosus* var. *petiolata*.—"Java, in Blambangan (Hors F.)."



Type of *A. longissima*.—"Fly-River; D'Albertis." Papua, 1876, No. 6424 in herbarium of R. Inst. studi Sup. Firenze. Described as glabrous, with very short petioles, leaf blades (ex photo of type) up to 24 cm. long and 8 cm. broad. With a close examination of its pedicels and remnants of calyx lobes it may be possible to place this species in its proper position with greater confidence.

Type of *A. villosa* var. *glabra*.—"Ex insula Noesabaroeng tantum nobis cognita."

Type of *A. somersetensis*.—"Near Mr. Jardine's house, Somerset."

Specimens cited by Markgraf (1927) as *A. villosa* f. *calvescens*.—"Bismarck-Archipel: Neu-Pommern, ohne Fundort, fruchtend i.J. 1901—*Parkinson* 1; Gazella-Halbinsel, in den Wäldern des Baining-Gebirges, steril Sept. 1905—*Rechinger* 3989 (Naturhis. Mus. Wien); Simpsonhafen, im Sekundärbusch, blühend und fruchtend 16 Sept. 1908—*Rudolph* 15 (einh. Name: *a ituwe*); Matupi, blühend Okt. 1901—*Schlechter* 13684; ebenda, blühend und fruchtend Sept. 1905—*Rechinger* 4114 (Naturhist. Mus. Wien). Neu-Mecklenburg, Namatanai, bei Salosalo auf Schwemmland, blühend und fruchtend 15 Juni 1910—*Peckel* 460 (einh. Name; *a itub*). Kei-Inseln: Kei keteil a. tual, mit Blütenknospen und Früchten. Aug. 1873—leg. *Beccari* (Herb. Florenz 6413)." I have not seen any of these collections. Judging from his annotated determinations of Queensland specimens and his published synonymy Markgraf's concept of *A. villosa* includes *A. Muelleriana*. Therefore there is ground for doubt regarding the true position of this form. Markgraf noted that his form was not *A. villosa* var. *glabra*, as the leaves of the latter were said to be hardly separable from those of *A. angustifolia*, a species which unlike the New Guinea plant has small narrow leaves. As Markgraf observed, the typical leaves of *A. spectabilis* are larger than those of *A. angustifolia*, but there are frequent examples of small leaves in this and in all the other large-leaved species in the genus. Leaf size is not a dependable character in *Alstonia*.

19. *Alstonia ophioxylodes* F. Muell., *Fragm.* 1: 57. 1858.

Petioles 1.5–2.5 cm. long; leaf blades 6–12 cm. long, pubescent beneath, the lateral nerves about 25 pairs, 3–6 mm. apart. Inflorescence and flowers like those of *A. spectabilis* except that the indumentum on the pedicels and calyces is of more loosely disposed and more spreading hairs.

ORIGINAL CITATION.—"Ad ripas fluviorum et clivos rupestres terrae Annhemicae."

LECTOTYPE.—*F. Mueller s. n.*, Fitzmaurice Rv. (Gray Herbarium).

DISTRIBUTION.—Australia: Northern Territory: *F. Mueller* (lectotype; fl.; K, GH), *F. Mueller* (Victoria Rv.; fl.; K).

20. *Alstonia Muelleriana* Domin, in *Biblioth. Bot.* 22 (Heft 89): 527. 1928.

*A. Muelleriana* var. *parvifolia* Domin, in *Biblioth. Bot.* 22 (Heft 89): 1081. 1928.

Trees up to 20 or 25 m. tall. Leaves usually 3-verticillate; petioles 0–2 cm. long; leaf blades usually 9–18 cm. long and 3–8 cm. broad, varying from glabrous to densely villose beneath, the lateral nerves 14–17 pairs, 5–13 mm. apart. Inflorescence with numerous crowded flowers, the pedicels short, ascending; calyx turbinate, tomentose outside, the calyx lobes ovate to lanceolate, densely pubescent outside and inside, not reflexed; corolla tube about 2.5 mm. long, tomentose outside, corolla lobes linear to oblong-lanceolate, about 3 or 4 times longer than broad, 2.2–4 mm. long; stamens inserted slightly above middle of tube, the anthers 0.9–1.1 mm. long.

TYPE.—"Endemisch in Nordost-Queensland.-Regenwalder bei Lake Eacham und Yarraba (Domin II. 1910). *A. villosa* F. v. Muell. *Fragm.* VI. 117 (1868). . . . Cf. descriptionem apud Bentham *Fl. Austr.* IV. 313 (1869)."

DISTRIBUTION.—Northern Australia and in Papua. Frequent in the northern part of Queensland; probably grows also in the Northern Territory. Rain forests and sometimes in savannas, usually at low altitudes (reported up to 800 m.).

Australia.—Queensland: *F. M. Bailey* (Granite Creek; Bri), 121 (Bellenden Ker Hills; Bri); *J. F. Bailey* (Cook Dist.; Bri); *Blake* 14750 and 15263 (Cook Dist.; Bri); *Brass* 1953 and 2529 (A); *Cowley* 98D (Cook Dist.; Bri); *Dallachy* (Rockingham Bay; GH); *Dogerell* (Kuranda; A), A37 (Cook Dist.; Bri); *Helms* 1224 (A); *C. T. White* 11726 (Cook Dist.; A); *Kajewski* 1080 and 1469; *Michael* 638 (GH); *C. T. White* (Mourilyan; A).

Papua.—*Brass* 5761 (A, NY), 6563 and 7953 and 8172 and 8373 and 8493 (A).

The Queensland material which has generally been known as *A. villosa* is closely related but clearly distinct from the Blume species (here referred to *A. spectabilis*). Mueller did not accept it without reservation as identical with *A. villosa*; its distinctive character was first noted by Koorders and Valetton (1894: 123).

Type of *A. Muellieriana* var. *parvifolia*.—"Savannenwälder am Waterfall Creek bei Yarraba (Domin I. 1910)." The smaller leaves ("5–8 cm. longis et 1.5–2 cm. latis") which characterize this variety are not diagnostic.

21. *Alstonia macrophylla* Wall. ex. G. Don, Gen. Syst. 4: 87. 1837.

*A. macrophylla* Wall., Num. List 1648. 1829 (nom. nud.).

*A. costata* Wall., Num. List 1649. 1829 (nom. nud.); Wall ex. Miquel, Fl. Ind. Bat. 2: 439. 1856. Non R. Br. 1811.

*A. macrophylla*  $\beta$  *glabra* A. DC., Prod. 8: 410. 1844.

*A. Batino* Blanco, Fl. Filip. ed. 2, Suppl., 589. 1845.

*A. pangkorensis* King & Gamble, in Jour. As. Soc. Beng. 74 (2): 442. 1907.

? *A. paucinervia* Merrill, in Philip. Jour. Sci., Bot. 5: 224. 1910.

*A. oblongifolia* Merrill, in Philip. Jour. Sci., Bot. 10: 65. 1915.

*A. macrophylla* var. *mollis* Merrill, Enum. Philip. Pl. 3: 322. 1923.

Trees usually 10–20 m. tall. Leaves like those of *A. spectabilis*, usually 4-verticillate.

Inflorescence profusely flowered, divaricately branched, the pedicels long, up to 4 mm. long, slender (about 0.3 mm. diam.); calyx less than 1.5 mm. long, gray-puberulent to glabrous; calyx lobes usually 0.4–1.3 mm. long, ciliate, inside slightly puberulent near apex or glabrous; corolla tube 4.5–6 mm. long, glabrous outside or very sparsely pubescent toward upper part; corolla lobes 3.7–5.7 mm. long, ciliate; stamens inserted about  $\frac{1}{4}$  from throat of corolla tube, the anthers about 1 mm. long.

TYPE.—"Native of Penang. Wall. Cat. no. 1648."

ILLUSTRATIONS.—Colthurst, Familiar Fl. Trees in India (1924) 92 (photo of leafy br. and infl.); Ahern, Philippine Woods (1901) 33 (leafy br. and infl., fl., frs.); Vidal, Fl. For. Filip. Atlas (1883) t. 66, fig. A (leafy br. and infl., fl. analysis, fr.); Lecomte, Fl. Gen. Indo-Chine (1933) 3: 1133, fig. 130 (fl., fl. analysis); Wettstein, Handb. Syst. Bot., ed. 2 (1911) p. 462, abb. 317, fig. 9 (seed); Ettingshausen, Blatt-Skel. DiKot. (1861) t. 30, fig. 4 (leaf skeleton).

DISTRIBUTION.—Siam and the Malay Peninsula to Indo-China and throughout the Philippines; also in Borneo, and probably in Sumatra, Biliton, and Celebes.

Siam.—*For. Dept. Siam* 13; *Kerr* 11439 (A), 12732 (Surat; A), 14792 (A), 19248 (Patalung; A); *Put* 697 (Kow Samui; Mo).

Indo-China.—*Poillane* 882 (Hatien; A).

Philippines.—Balabac: *Bur. Sci.* 15654 (L), 49678 (UC). Cebu: *For. Bur.* 6410 (Mo). Guimaras: *For. Bur.* 250. Luzon: *Abern* 75 (US); *Bur. Govt. Lab.* 219; *Bur. Sci.* 1084 (G, US), 1895, 27220 (A), 44692; *Cuming* 505, 782 (G, L, Mo, P); *Elmer* 14468 and 15515; *For. Bur.* 3151 and 3424 and 7113 and 8322, 17128 (type coll. *A. m.* var. *mollis*; L), 17903 (A), 18726 (type coll. *A. paucinervia*; US), 19806 (F), 23535 (A), 23855 (UC), 24811 (A), 24985 (GH), 25032 (A), 25455 (A), 30201 (Bri, UC); *Gates* 6993 (F); *Lober* 3883 (US), 4020, 4021 (US); *Merrill Sp. Blancoanae* 335, 659; *Sulit* 60; *Whitford* 652, 864. Minda-



nao: *For. Bur.* 29612 (UC). Mindoro: *Bur. Sci.* 39586 (A), 46440 (A); Merrill 2378 (US). Palawan: *Curran* 4495 (type coll. *A. oblongifolia*; K, NY, US); *Elmer* 12929; *For. Bur.* 29279 (A). Panay: *For. Bur.* 23956 (Mo). Romblon: *Elmer* 12157. Sibutu: *Herre* 1201, 1202 (A).

Malay States.—*Corner* (Trengganu; Sing); *Curtis* 378 (Penang); *Maingay* 1066/2 (L), 1070/2 (GH); *Scortechini* 1024 (type coll. *A. pangkorensis*; fr.; Cal); *Sing. Field No.* 252 and 31950 (Penang; Sing), 33422 (Kelantan; Sing); *Wallich* 1649 (Penang).

British North Borneo.—*Balajadin* 4030 (Kudat; Sing); *For. Dept. Sandakan* 3680 (UC); *Villamil* 348 (A); *Castro and Melegrito* 1492 (Banguey; A).

Sumatra.—*Boschproefst.* 5250 (Tapanoeli Silindoeng; sterile; L).

Biliton.—*Herb. Biliton* 84 (sterile; L).

Celebes.—*Koorders* 16041, 16042, 16044, 19745 and 24068 (Minahassa; sterile; L).

Java.—*Brink* 5399 (Batavia; L); *Hort. Bot. Bog.* 286 (cult.; US); Merrill (cult. IV-A-65).

India.—*Haines* 3994 (Paraganas; prob. cult.; K).

Mauritius.—*Horne* (cult.; K).

VERNACULAR NAMES.—Philippine Islands: *Batino*, *Cayacayao*; Annam: *Cay So Dua*; North Borneo: *Bakau*.

Type of *A. macrophylla*  $\beta$  *glabra*.—"Insula Penang. *A. costata* Wall. list n. 1650" (error for 1649). Don first called attention to this plant: "... does not appear to differ from *A. macrophylla*, unless in the leaves being glabrous, narrower, and the veins more distinct." De Candolle assigned a varietal name to it on basis of Don's comment. Examination of the numerous collections now available make it obvious that the characters given for this variety do not hold. The leaves of the type collection are not entirely glabrous but faintly pubescent along the veins on the underside.

*A. Batino*, described from the Philippines without citation of type, is referred with pro-

priety to *A. macrophylla* by Merrill. Blanco's *Echites trifida*, which was a misapplication of Jacquin's name, is also referred with certainty to *A. macrophylla* by Merrill.

Type of *A. pangkorensis*.—"Dindings: Pangkor Island, *Scortechini* 1024." Described from a fruiting specimen and placed under "Species of Doubtful Position" by King and Gamble, the type apparently represents old leaves, greatly enlarged and with lateral nerves more distant and the veins more boldly raised than is usual for *A. macrophylla*. The calyces and pedicels, as well as the fruits, are characteristically those of *A. macrophylla*.

Type of *A. paucinervia*.—"Luzon, Province of Camarines, Paracale, *For. Bur.* 18726 *Darling*, Mar. 19, 1910, in forests at an altitude of about 70 m., locally known as *batino*." Flowering material from New Guinea (in the present paper named *A. Brassii*) has been identified by Markgraf as belonging to this species. The vegetative and fruiting characters of the Philippine type and the New Guinea plants are very similar, but not reliable. It is most likely that *A. paucinervia* is merely an atypical form of *A. macrophylla* as Merrill himself suggested.

Type of *A. oblongifolia*.—"Palawan, in old clearings near Puerto Princesa, *For. Bur.* 4495 *Curran*, June 5, 1906." It seems that because of its small leaves the type was originally compared with *A. angustifolia*. The flowers are typically those of *A. macrophylla*, which not infrequently also has small leaves.

Type of *A. macrophylla* var. *mollis*.—"F. B. 17128 *Curran*." As pointed out by Markgraf (1927: 178) the type of the species is the pubescent form.

Forbes and Hemsley (1889: 95) cite, from Yunnan, an *Alstonia* sp. "allied to *A. macrophylla* Wall., but apparently different ... (*Anderson!*) herb. Kew." I have seen from Yunnan only species in the  $\S$  *Blaberopus*.

It has been estimated (*fide* Macmillan) that 1,000 seeds of *A. macrophylla* weigh less than a gram.

21a. *Alstonia macrophylla* var. *acuminata* (Miq.) Monachino, stat. nov.

"*Cofassus Citrina*" Rumph., Amb. 3: 30. t. 15. 1743.

*A. acuminata* Miq., in Ann. Mus. Bot. Lugd. Bat. 4: 140. 1869.

*A. subsessilis* Miq., in Ann. Mus. Bot. Lugd. Bat. 4: 140. 1869.

The calyx lobes are usually more than 1 mm. long, sharper at apex than those of the typical form, ciliate, otherwise glabrous; anthers about 1.1 mm. long. In the material examined the leaves are glabrous and their veins are more boldly raised than is usual for the typical form; the flowers are in poor condition.

TYPE.—"Amboina: et forma foliis anguste ovatis obtuse acuminatis in Ceram: *Teysmann*."

DISTRIBUTION.—Apparently confined to Amboina and Ceram. The typical species is possibly found in Celebes to the west, and *A. Brassii*, which is very closely allied to *A. macrophylla*, is in New Guinea to the east; otherwise this variety is distantly isolated from the principal range of the species and there is no other relative from which it might have been derived.

Amboina.—*de Fretes* 5574 (type coll. *A. subsessilis*; L); *de Vries and Teysmann* (type coll. *A. acuminata*; L); *Neth. Ind. For. Serv.* 25995 (A); *Robinson Pl. Rumph. Amb.* 77 (GH, K, L, NY, US); *Teysmann (Herb. Bog.* 5166; K).

Ceram.—*de Vries and Teysmann* (L).

Java.—*Hallier f.* 43 (cult., Hort. Bot. Bog. IV-A-55; L); *Merrill* (IV-A-55; NY, US).

VERNACULAR NAMES (*fide* Heyne).—*Ajoeran*, *Aoeran*, *Oeken*, *Poele Batoe*, *Pole*.

"*Cofassus Citrina*" was referred to *A. acuminata* by Heyne (1917: 63) and to *A. subsessilis* by Merrill (1917: 427). Although Rumphius' illustration is poor and his description is not definitive, there is fair circumstantial evidence in favor of accepting this identity. Rumphius states that the plant is rare and presents the following distribution: "Hitoe circa pagum Lima, & in Leytimora in montibus Oerimissen, item in Java & Baleya."

Type of *A. subsessilis*.—"Amboina ubi Poelék-batoe vel Lassi oetan vocatur: *De Fretes*." It consists of sterile material and is characterized chiefly by its subsessile leaves. Flowers are present in *Herb. Bog.* 5166, which has the leaf character of this form.

Merrill pointed out that IV-A-55 cultivated in the botanic garden at Buitenzorg under the unpublished name of "*Alstonia hoedti* T. & B.," reported to have originated from Amboina, is apparently identical with *A. subsessilis*; Dakkus (1930: 17) names the plant *A. acuminata*.

22. *Alstonia Brassii* Monachino, sp. nov.

*A. macrophyllae* perintime affinis sed foliis glabris, pedicellis brevioribus crassioribusque minus quam 3 mm. longis, calyce ca. 2 mm. longo, lobis plus quam 1.5 mm. longis extus glabris vel glabrescentibus; staminibus prope mediam tubi corollae insertis.

Trees 18–24 m. tall. Petioles 0–1 cm. long; leaf blades usually 12–18 cm. long, 4–8 cm. broad, glabrous, the lateral nerves 15–20 pairs, 8–15 mm. apart. Inflorescence sparsely to profusely flowered, the ultimate branches less spreading than those of *A. macrophylla*; pedicels less than 3 mm. long, more robust than those of *A. macrophylla*, about 0.5 mm. in diameter; calyx about 2 mm. long, glabrous or nearly so; calyx lobes glabrous or glabrescent outside; glabrous inside, ciliate; corolla tube about 5.6–5.7 mm. long, glabrous or very sparsely pubescent outside; corolla lobes 4.7–7 mm. long, varying from well-ciliate to eciliate; stamens inserted slightly above middle of corolla tube, the anthers 1–1.3 mm. long.

TYPE.—*L. J. Brass* 5138, Papua, Mafulu, Central Division, forests of middle and lower slopes, altitude 1,250 m., very abundant; Sept. 30, 1933. (Type, NY. Bot. Gd.; isotype, Arnold Arboretum.)

DISTRIBUTION.—The entire island of New Guinea; sometimes common. Reported from forests at altitudes of 180–1,800 m.

Papua.—*Brass* 630 (Bisiatabu; A), 5138 (type coll.); *H. O. Forbes* 125 (Sogeri Region; BM, K, L).



Northeast New Guinea.—*M. S. Clemens* 862 (Morobe District, Sattelberg; A), 124 and 4567 (Morobe District; A); *Schlechter* 16255 (Kaiser-Wilhelmsland, Wobbe; A, Bri, F, G, L), 19663 (Kaiser-Wilhelmsland, Dischore; A, Bri, F, G, K, L); *For. Herb. N. Guinea* 571 (Joangey; Bri; "*Qweta*").

Netherlands New Guinea.—*Neth. Ind. For. Serv.* 30363 (Seroei, Japen; A).

The type has been identified by Markgraf (in herb.) as *A. macrophylla* var. *glabra*, and other specimens both as *A. macrophylla* var. *glabra* and *A. paucinervia* (Markgraf, 1927: 178, 179). The original variety, however, is not separable from typical *A. macrophylla*, with which the dubious *A. paucinervia* is probably also synonymous. The conclusion that *A. Brassii* is distinct from *A. glabriflora* is based almost solely upon the description of Markgraf's species. Markgraf examined all of the specimens here cited under *A. Brassii* and did not identify any of them with his *A. glabriflora*.

The type is noted as a tree up to 20 m. tall; sap milky; leaves glossy; flowers numerous, foetid, corolla tube pale pink, lobes cream-colored. C. T. White (1929: 260) describes 630 as a tall and slender laticiferous tree, 18–24 m. tall, 50–60 cm. girth, unbranched to near top, wide light-crowned.

23. *Alstonia glabriflora* Markgraf, in Bot. Jahrb. 61: 179. 1927.

Leaves small, 12–20 cm. long, glabrous. Calyx 2 mm. long, glabrous, the lobes erect, ciliate; corolla glabrous outside, the tube 4 mm. long, the lobes oval, 2 mm. long, twice as long as wide, at most two-thirds as long as tube, glabrous above, ciliate only toward the base; anthers inserted near throat, 1 mm. long. (Compiled from the original description.)

TYPE.—"Nordost-Neuguinea: Sepikgebiet, Felsspitze, im montanen Buschwald, 1400–1500 m. ü M., blühend 6 Aug. 1913—*Leder-mann* 12649."

24. *Alstonia linearis* Benth., Fl. Austral. 4: 314. 1869.

Branchlets very slender, 2 mm. or less in diameter, leaves narrowly linear, 4–9.5 cm. long and only 1.5–3 mm. broad, often falcate, lateral nerves about 40 pairs, about 1 mm. apart. Flowers not known.

COTYPES.—"N. Australia. Cliffs of Brunswick Bay and Regent's River, N.W. coast, *A. Cunningham*."

LECTOTYPE.—*A. Cunningham s.n.*, Western Australia, north coast, cliffs of Brunswick Bay; fruiting, 1820. (Kew.)

DISTRIBUTION.—Known only from the original collections on the coast of the Kimberley Division of Western Australia.

Western Australia.—*A. Cunningham s.n.* (type), 204 (coll. no. ?; Regent Rv.; K).

### § DISSURASPERMUM

Shrubs or small trees, 1–15 m. tall, often of greatly varying sizes in the same species. Leaves opposite, except in *A. Legouixiae* (and *A. saligna*?) where 3-verticillate as well as opposite; petioles manifest, slightly dilated at base; blades usually more or less elliptic and cuneate at base, sometimes coriaceous, the reticulation manifest except in the thickly coriaceous leaves. Calyx lobes ovate, usually 0.6–2 mm. long and 1–2 mm. broad, obtuse to somewhat acute at apex, rarely ciliate (*A. constricta*), otherwise glabrous; corolla tube short, mostly 2–5 mm. long, glabrous outside or rarely minutely puberulent; corolla lobes mostly longer than corolla tube, usually glabrous outside, rarely manifestly ciliate, sometimes with very faint sparse microscopic cilia; stamens inserted mostly at about middle of corolla tube; anthers generally 0.7–1.5 mm. long; ovary glabrous, the style short, usually 0.5–1.5 mm. long. Follicles slender, glabrous; seeds usually with a more or less elliptic body which is lightly pubescent on faces, generally about 2 mm. broad, the tails varying from entire to lightly lobed to deeply bifurcate.

Representatives of this section are common from Australia to the far eastern Pacific.

In the Pacific islands east of New Caledonia, starting from the New Hebrides and extending to the Marquesas, there are only two clearly dis-

inct species, *A. costata* and *A. vitiensis*. Between them there is a long series of closely intergrading polymorphic forms weakly grouped around vague foci. These form-groups are hardly definable except as overall tendencies toward either the long-tailed seeded *A. vitiensis* or the short-tailed seeded *A. costata*; they appear to be best associated with ecological-geographical factors. Insular distribution here seems to have a marked influence on morphological modifications of the species. Except for seed structure, in which moderate trust may be placed, no single morphological character is dependable. Flowers of the different species or varieties are essentially uniform, variations being more of an individual nature rather than diagnostic; vegetative features are inconstant and serve merely to describe typical specimens. For convenience, four species and two varieties are here recognized; there are frequent examples of doubtful intermediates. The extreme polymorphy in the species of the *costata-plumosa* series recalls the similar phenomenon observed in the "obovata-group" of *Planchonella*. See the interesting discussion of *Planchonella* and *P. sandwicensis* by H. J. Lam (1942: 3, 16). The variations in flower dimensions, length of corolla tube, and length and width of corolla lobes, and variations in degree of pubescence within the corolla lobes are profound and disconcerting. Extensive field and statistical studies accompanied by vast series of specimens are necessary for their proper evaluation.

25. *Alstonia constricta* F. Muell., Fragm. 1: 57. 1858.

*A. mollis* Benth., Fl. Austral. 4: 315. 1869.

*A. constricta* var. *mollis* F. M. Bailey, Synopsis Queensl. 308. 1883.

*A. constricta* var. *montmariensis* F. M. Bailey, in Queensl. Fl. Agr. Jour. 26: 198. t. 19, fig. 3. 1911.

Petioles 2–4 cm. long; leaf blades very variable in shape, width, and pubescence, narrowly lanceolate to broadly elliptic, often falcate, 9–15 cm. long, (0.5–) 1–6 cm. broad, acuminate or narrowed and usually acute at apex, varying

from velvety-villose on both sides to entirely glabrous, the lateral nerves 13–16 pairs, 5–7 mm. apart, strongly arcuate and ascending. Inflorescence velvety-villose to glabrous, flowers rather crowded, pedicels very short (2 mm. long or less); calyx lobes ciliate; corolla tube 2.3–3.6 mm. long, densely papillose at throat inside; corolla lobes ligulate, 7–9 mm. long, sparsely pubescent above the bearded base within, sparsely ciliate. Follicles 6–20 cm. long; seeds lanceolate, 7–12 mm. long and 2–3 mm. broad, narrowed at both ends, hardly caudate, usually with a shallow sinus at one or both ends, the cilia short, up to about 2 mm. long, light brown.

COTYPES.—"Prope montem Pluto. *Thom. Mitchell, Eques.* In pratis basalticis inter flumina Burdekin et Burnett."

LECTOTYPE.—T. L. Mitchell 261, Queensland, Mt. Pluto.

ILLUSTRATIONS. — Queensl. Agr. Jour. (1911) 26 (4): t. 19; also Bailey, Compr. Cat. Queensl. Pl. (1913) 323 (leafy br. and infl., fr.); loc. cit. (as var. *mollis*; leafy br. and infl., fl. analysis); loc. cit. (as var. *montmariensis*; leafy br. and infl.); Agr. Gaz. N. S. Wales (1908) 19: 106 (photo of entire tree showing habit).

DISTRIBUTION.—Australia, frequent in Queensland and New South Wales. Reported from monsoon forests, sandy country, scrub, secondary growth, and roadsides; said to be somewhat of a pest in cultivated grounds.

Queensland.—F. M. Bailey (Warrego; Bri), (type coll. var. *montmariensis*; fl.; Bri, K); Bancroft (Eidsvold; 1910; Bri); Bick (Roma; Bri); Blake 14791 (Port Curtis; Bri), 15299 (Sellheim; Bri), 15358 (Biloela; Bri); Bowman (Nerkool Creek; fr.; K); Brass and White 25 (Warrego; A); M. S. Clemens (Charleville; Bri); Everest 796 (Maranoa; A), 2156 (Blackall; A); Fitzalan (Natal Downs; K); W. D. Francis (Bingegong; Jericho; Bri); Grove 138 (Nanango; Bri); Helms 1243 (A); Jensen (Dividing Range; Bri); Keys 725 (Mt. Perry; Bri); Longman (Forest Gate; K); MacGillivray 1017 (Charleville; Bri), 2187 (Bar-



coo Rv.; Bri); *Mitchell* 261 (type; K), 323 (K), 368 (type coll. *A. mollis*; fl.; K); *F. Mueller* (bet. Burdekin and Burnett Rvs.; fl. and fr.; K); *Murray* 10 (Mt. Lookout; Bri); *C. F. Plant* (Charters Towers; Bri); *Roe* 26 (Darling Downs; Bri); *Simmons* 9 (Fairy Bower; A); *Tambling* (Eulo; Bri); *Thozet* (Rockhampton; G); *Trist* 37, *Weatherhead* (near Benarkin; Bri); *C. T. White* (Darling Downs; Moreton; Bri), 9567 (Roma; A).

New South Wales.—*Boorman* (Marrabri; Emerald; Lake Eliza; L, UC, US); *Cleland* (Moree; Bri); *Cunningham* 114 (Oxley; BM, K); *Gandoger* (Mo); *Goodwin* (Darling Rv.; K); *Kenny* (Childers; Bri); *McDougall* (Bourke; G); *C. T. White* (Rosewood; Bri), 12702 (McIntyre Brook; Bri).

VERNACULAR NAMES.—*Bitter Bark*, *Quinine Tree*.

*A. constricta* is described as having little or no latex in its bark, latex present in young shoots. Leaves somewhat pendulous. Flowers cream-yellow or white and sweetly scented. The plant is strongly trimmed by stock, and forms root-suckers.

Type of *A. mollis*.—"Queensland. Barcoo river, near Mount Northampton, *Mitchell*."

Type of *A. constricta* var. *montmariensis*.—"Mount Maria, Warrego, F.M.B., 1876; Eidsvold, T. L. Bancroft, 1911."

Pubescence and leaf width are entirely erratic characters in this species, having neither consistency in themselves nor concomitance with any other taxonomic feature or geographical distribution, and therefore cannot serve for even varietal segregation. Narrow leaves such as were used to characterize the var. *montmariensis* (6 mm. broad) and much broader ones (2.5 cm.) are sometimes found on the same branch. Plants with softly villöse leaves of the *mollis* type are often growing intermingled with the glabrous form.

In his publication of var. *mollis*, Bailey made no mention of Bentham's binomial *A. mollis*. He did not cite the type for his variety, and it is not clear whether a new variety or a reduction of Bentham's species was intended.

Bentham (1869: 314) notes concerning *A. constricta*: "This species differs from the rest of the genus, and approaches *Tabernaemontana* in habit and foliage, and usually in the presence of small glands at the base of the calyx inside." The species is markedly distinctive, but no vestige of intra-calycine glands has been detected by me.

26. *Alstonia lanceolata* van Heurck & Muell. Arg., in van Heurck, Obs. Bot. 199. 1871.

Petioles 0.5–1 cm. long; leaf blades chartaceous, lanceolate or elliptic, 10–13 cm. long and 1.5–3 cm. broad, narrowed and somewhat acuminate at apex, glabrous, the lateral nerves numerous, about 40 pairs, 2–4 mm. apart. Inflorescence very sparsely and loosely flowered, the peduncles very short, about 1 cm. long, sparsely branched, pedicels up to 6 mm. long; corolla tube about 5 mm. long; corolla lobes somewhat shorter than corolla tube, about 4 mm. long, well-pilose the entire face within, manifestly ciliate. Follicles 25 cm. long; seeds about 16 mm. long, slender-caudate at both ends, tails up to 5 mm. long.

TYPE.—"Nova Caledonia ad Wagap: *Vieillard* 921 (in herb. van Heurck)."

New Caledonia.—*Compton* 1271 (Mt. Kanala; fr.; BM), 1719 (Ignambi; fl.; BM); *Schlechter* 15565 (Oubatche; fl.; G, K, L); *Vieillard* 921 (type coll.; fl.; G, GH, K).

27. *Alstonia Vieillardii* van Heurck & Muell. Arg., in Flora 53: 171. 1870.

*A. Duerkheimiana* Schlechter, in Tropenpf. 7: 528. fig., p. 529. 1903.

Branches stout. Petioles 1.5–5 cm. long; leaf blades large, 9–36 cm. long, 4–22 cm. broad, usually acuminate at apex, softly pubescent beneath, sometimes glabrous, dull above, the lateral nerves 16–22 pairs, 7–18 mm. apart. Inflorescence usually pubescent, the ultimate branchlets and pedicels adpressed or ascending, many-bracteate; flowers sulfur-yellow; corolla tube 8.5–9.2 mm. long, minutely puberulent outside near middle; corolla lobes carnose,

shorter than corolla tube, 3.5–8 mm. long, puberulent and short-pilose toward base inside; stamens inserted at about 1/3 from base of corolla tube. Follicles 21–30 cm. long; seeds 7–9 mm. long, the tails short, less than 2 mm. long.

TYPE.—“Habitat secus Toondu in Sinu Tupiti Nova Caledoniae: *Vieillard* 924 (in herb. van Heurck).”

ILLUSTRATIONS.—*Tropenfl.* (1903) 7: 529 (type of *A. Duerkheimiana*; br., infl., fr., lvs., fl. analysis).

DISTRIBUTION.—New Caledonia—*Compton* 817 (Dumbea; BM), 2010 (Comboui; BM); *Deplanche* 67 (L); *Franc* (Prony; A), 44 (Prony), 2450 (A); *Pancher* (K); *Schlechter* 14867 (Païta; GH); *Vieillard* 924 (type coll.; fl., G, GH, L); *C. T. White* 2054 (Mt. Mou; A).

The type of *A. Duerkheimiana* was not cited. Material determined as this species by Schlechter is available. The synonymy of *A. Duerkheimiana* with *A. Vieillardii* was discussed by A. Guillaumin (1911b: 230).

28. *Alstonia Roeperi* van Heurck & Muell. Arg., in Van Heurck, Obs. Bot. 201. 1871.

Branchlets stout (7–10 mm. diam.), leaf scars large; leaves closely resembling those of *A. Vieillardii* but markedly shining above; petioles 3–4 cm. long, fossate at axil; leaf blades 14–28 cm. long, 3–15 cm. broad, usually acuminate at apex, sometimes obtuse to rounded, pubescent beneath, sometimes glabrous, the lateral nerves 16–25 pairs, 1–2 cm. apart. Inflorescence with spreading branches, profusely flowered; corolla tube 3.7–4.1 mm. long; corolla lobes oblong-lanceolate, 4.4–5.7 mm. long, pubescence within sometimes extending from base to near apex. Follicles up to 22 cm. long; seeds 15–16 mm. long, the tails very long and slender, up to 8 mm. long.

TYPE.—“Nova Caledonia ad Wagap: *Vieillard* 922 (in herb. van Heurck).”

New Caledonia.—*Caldwell* (Dumbea; K); *Compton* 671 (Mt. Dore; BM), 1518 (Ig-

nambi; BM); *Deplanche* 66 (K); *Franc* 21 (Dumbea), 42 (UC); *Pancher* (K); *Schlechter* 15445 (Oubatche; G); *Vieillard* 922 (type coll.; G); *C. T. White* 2038 (Mt. Mou; A), 2162 (Dumbea; A).

Collections of this species have been almost universally determined as *A. plumosa*. The identity of *A. Roeperi* with the latter is possible (see discussion under *A. plumosa*).

29. *Alstonia plumosa* La Bill., Sert. Austr. Caled. 28. t. 32. 1824.

Branchlets rather stout; petioles 6–12 mm. long; leaf blades elliptic, 2.5–11 cm. long, 1.2–3.5 cm. broad, rounded to obtuse or somewhat acute at apex, the lateral nerves about 15 pairs, arcuate and distantly spaced. Inflorescence crowded; corolla tube short; corolla lobes longer than corolla tube, oblong, pubescent within; stamens inserted below middle of corolla tube. Follicles 7–13 cm. long; seeds 24 mm. long, the tails long and slender, up to 9 mm. long. (Compiled from original description and photo of type.)

TYPE.—*La Billardièrre*, New Caledonia.

ILLUSTRATIONS.—Type (leafy br. with infl. and fr.; fl. analysis; seeds).

Specimen examined.—Type (photo).

The type is now deposited in the Instituto Botanico dell' Università, R. Erbario Coloniale, Firenze, Italy. Known to me only from the original description and from a photograph of the type, I have failed to allocate the species. Of the New Caledonia *Alstonia* examined, *A. plumosa* is closest to *A. Roeperi*, of which I have seen the isotype and rather ample collections. In maintaining this view regarding affinity, great reliance is placed on seed character. The latter species, in fact, has been almost universally distributed as *La Billardièrre's* plant. The name *A. plumosa* has also been widely applied to various species from Fiji and Samoa. The superficial appearance of the plant as seen in the plate might suggest a small-leaved glabrous form of *A. vitiensis*, *A. Reineckiana* or *A. montana*. (The seeds of the latter are



obviously different from those illustrated for *A. plumosa*.) However, up to the present time, I have found all the New Caledonian species of *Alstonia* to be endemic, and there is no evidence that La Billardiere's itinerary (*Voyage à la Recherche de la Pérouse*) included the Fijian islands. It stands to reason that the possibility is not precluded that *A. vitiensis* or *A. Reineckea* may be found in New Caledonia, although there is no such evidence now at hand. Not counting *A. plumosa*, nine species are definitely known from New Caledonia; five of these are represented by only one or two collections. It is quite possible that *A. plumosa* is a rare species which has not yet been rediscovered. It is also barely possible that *A. plumosa* is a very unusual form of *A. Roeperi*—a form with small blunt glabrous leaves—for leaf character is hardly reliable in this group. Completely glabrous, blunt-leaved forms do occur in *A. Roeperi*, for example, in *Compton 1518* cited above. In a closely knit group such as *plumosa-costata* in which floral characters are almost identical and diagnostic differences of any kind are very difficult to discern even with aid of botanical specimens, it is hopeless to attempt to form a clear idea of *A. plumosa* without at least an examination of the type.

30. *Alstonia vitiensis* Seem., Fl. Vit. 430. 1873.

*A. villosa* Seem., Fl. Vit. 161. 1866 (homonym); non Blume, Bkjd. 16: 1038. 1826.

Typical branchlets very stout, up to 1.5 cm. in diameter, fistulose, leaf scars large; petioles 2.5–9 cm. long, conspicuously fossate at axil; leaf blades often immense, 8–45 cm. long, 4–27 cm. broad, rounded, or shortly blunt-acuminate at apex, mostly obtuse at base, softly villose (pubescent series) to glabrous beneath (glabrous series), generally less shining above than in *A. Roeperi*, the lateral nerves 12–16 pairs, 1.5–3 cm. apart. Inflorescence many-flowered, ample, and rather spreading; calyx 1–2 mm. in diameter; corolla tube (2.2–) 3.9–4.4 mm. long; corolla lobes linear-lanceolate, longer than

corolla tube, 4–8 mm. long, pilose within only at base to entire face. Seeds 13–18 mm. long, the tails long and slender, up to 7 mm. long.

TYPE.—"Viti Levu (*Seemann 318*). Possibly Deplanche's n. 66, from New Caledonia, may be identical with this species, which I collected in fruit only, and distributed under the erroneous name of *A. plumosa*, Labill." *Deplanche 66* is *A. Roeperi*.

ILLUSTRATIONS.—Bul. Bernice P. Bishop Mus., Honolulu, 74:65. 1935. (leafy br., fr., seed); Jour. N. Y. Bot. Gd. (1945) 46: 112 (glabrous-leaved series; leafy br. and infl., fl., fr.).

DISTRIBUTION.—Common in Fiji; a dubious form in the Solomon Islands. Reported from rain and open forests, and from coastal thickets; altitude 30–600 m.

Pubescent-leaved series.—Fiji: *Horne 515* (GH); *Storck*. Taviuni: *Gillespie 4790* (GH, UC). Viti Levu: *Degener 15266*; *Gillespie 2467, 3040* (UC), *3623, 3653, 4228* (UC), *4273* (Bish); *Greenwood 361A*; *Meebold 16787* (Bish); *Parks 20900* (UC); *Petersen 3*; *Seemann 318* (type coll.; fl., fr.; GH, K); *Setchell and Parks 15052* (UC).

Glabrous-leaved series.—Fiji: Viti Levu: *Degener 15040, 15062, 15124, 15153*; *Gillespie 2912* (det.? US); *Meebold 16716* (det.? Bish); *St. John 18301* (Bish). Vanua Levu: *Degener and Ordóñez 14022*; *A. C. Smith 1701*. Kandavu: *A. C. Smith 251*. Solomon Islands: Ysabel Island: *Tiratona*: *L. J. Brass 3404* (rain forest, alt. 600 m.; fl.; L).

VERNACULAR NAMES.—*Mbule*, *Ndranga*, *Soroua*.

The glabrous-leaved series of specimens has a hardly appreciable tendency toward a broader calyx and a shorter (2.2–3.8 mm. long) corolla tube. The leaves are frequently smaller and easily confused with those of *A. Reineckea* and *A. montana*.

30a. *Alstonia vitiensis* var. *novo-ebudica* Monachino, var. nov.

A forma typica speciei foliis lanceolatis ad basin apicemque plusculum acuminatis, tubo

corollae 2.2–3 mm. longo, et seminibus 22 mm. longis, caudis usque ad 10 mm. longis recedit.

Petioles 2 cm. long; leaf blades lanceolate, 6–16 cm. long, 4–7 cm. broad, bluntly short-acuminate to greatly narrowed and sharp-pointed at apex, tapering at base, glabrous or faintly barbate on midrib beneath, the lateral nerves about 11 or 10 pairs, 1–2 cm. apart. Inflorescence profusely flowered; corolla tube 2.2–3 mm. long; corolla lobes about 6 mm. long; style about 0.8 mm. long. Seeds 22 mm. long, tails up to 10 mm. long.

TYPE.—*S. F. Kajewski* 292, Eromanga Island, Dillon Bay, altitude 300 m., rain forest and red soil bracken country; May 23, 1928. Small tree 8 m. tall; fl. white; fr. 25 cm. long. "Nev-yev-vi-are." (New York Bot. Gd.)

DISTRIBUTION.—New Hebrides, sometimes common; reported from rain forest, poor volcanic soil, red soil, and bracken country; altitude 50–300 m.

New Hebrides.—Eromanga: *Aubert de La Rue* (2nd voyage, 1935–6; fl.; A); *Kajewski* 292 (type coll.; fl. and fr.; A, K, NY). An-eityum Island: Anelgauhat Bay: *Kajewski* 740 (fl.; A, K, NY, US). Santa Cruz: Vanikoro: *Kajewski* 652 (fl. and fr.; A, Mo).

This is a weak and transitional variety. In general appearance it is markedly like the Solomon Island race of *A. vitiensis*, which, in turn, is similar to the glabrous-leaved series from Fiji.

*Kajewski* 292 and 740 are cited as "*Alstonia villosa* Seem. form. *calvescens* Markgraf" in Jour. Arn. Arb. 13: 19. 1932. The forma proposed by Markgraf is of *A. villosa* Blume, non Seem.

31. *Alstonia Reineckeana* Lauterb., in Engl. Jahrb. 41: 233. 1908.

?*A. Setchelliana* Christoph., in Bul. Bernice P. Bishop Mus., Honolulu, 128: 178, fig. 27. 1935.

Branchlets not stout; petioles 1.5–3 cm. long; leaf blades 7–20 (–25) cm. long, 3–9 (–12) cm. broad, short-acuminate or acute to rounded at apex, glabrous or rarely villose beneath, the

lateral nerves mostly 10–13 (–17) pairs, about 1 cm. apart. Inflorescence few- to many-flowered; calyx mostly 1.4–2.5 mm. in diameter below lobes; corolla tube 5–6 mm. long; corolla lobes narrowly lanceolate, 9–14 mm. long, pilose toward the base within. Seeds 12–18 mm. long, the tails long and slender, 4–8 mm. long.

TYPE.—"*Vaupel* 353. Savaii: am Maugamu." Samoa.

ILLUSTRATIONS.—Carnegie Inst. Washington, Publ. No. 341 (1924) t. 12, A (photo of leafy br., infl., leafy br., fr.). Type of *A. Setchelliana* (leafy br., infl., fr., seed).

DISTRIBUTION.—Frequent in Fiji and Samoa; reported from sea level to 1300 m. altitude; rain forest, scrub, or dense forest.

Fiji.—*Horne* 281 (GH). Viti Levu: *Gillespie* 2285 (det.? UC), 3506 (det.? US); *Greenwood* 1019 (det.? ). Vanua Levu: *A. C. Smith* 1603, 1683, 1795. Koro: *A. C. Smith* 1026. Moala: *Bryan Jr.* 343 (A). Taviuni: *Gillespie* 4836.

Samoa.—*Powell* 350 (K); *Vaupel* 382; *Wilkes*. Savaii: *Christophersen* 646, 3071 (US), 3540; *Christophersen and Hume* 1903; *Vaupel* 353 (type coll.; fl.; K, NY, US). Tutuila: *Christophersen* 1139 (cf. *A. Setchelliana*), 1257 (cf. *A. Setchelliana*; US), 1265 (type coll. *A. Setchelliana*; Bish); *Collarino* 381 and 387 (UC); *Wilkes* (US).

VERNACULAR NAMES.—*Ma'u'u Toga vao*, *Ndranga nggurunggura*, *O le fuai La'au Timei*, *Wa boli*.

Type of *A. Setchelliana*.—"Tutuila: forest, Alava Ridge, alt. 400 m. Nov. 7, 1929, *Christophersen* 1139; forest, ridge west of Pago Pago, alt. 300 m., Nov. 14, 1929, *Christophersen* 1257; forest ridge west of Pago Pago alt. 300 m., young fl., fr., Nov. 14, 1929, *Christophersen* 1265, type in B. P. Bishop Museum."

*A. Reineckeana* is a transitional species between *A. vitiensis* and *A. montana*, somewhat nearer to the former, which *A. Setchelliana* also more closely approaches. *A. Setchelliana* is possibly a distinct entity. *A. Reineckeana* may eventually prove to be a synonym of *A. Godefroyi* (see under Doubtful Species).



32. *Alstonia montana* Turrill, in Jour. Linn. Soc., London, Bot., 43: 32. 1915.

*A. Smithii* Markgraf, in Bul. Bernice P. Bishop Mus., Honolulu, 141: 125, fig. 65a. 1936.

Branchlets generally slender; petioles 1–3.5 cm. long; leaf blades 5–15 cm. long, 2.5–6 cm. broad, mostly obtuse or rounded at apex, sometimes bluntly short-acuminate, glabrous, the lateral nerves 11–22 pairs, 4–7 mm. apart. Inflorescence usually few-flowered; calyx 1.4–2.6 mm. diam. below lobes; corolla tube 3–6 mm. long; corolla lobes oblong-lanceolate, 3–7 mm. long, pilose toward base within; anthers 0.9–1.6 mm. long. Seeds 7–10 mm. long, the tails short, 2–4 mm. long, often obscurely lobed, their forks close to body of seed.

TYPE.—“Nandarivatu, by ‘Governor’s Seat’ in flower and fruit, Jan. 31, 1906, *in Thurn*, 58.” Fiji, Viti Levu.

ILLUSTRATION.—Type of *A. Smithii* (leafy br. and infl., leaf).

DISTRIBUTION.—Throughout Fiji and apparently also in Samoa; reported from rain forest, dense brush or thickets, open forest; altitude 500–1,200 m.

Fiji.—Wilkes. Viti Levu: *Degener* 13596, 14396 (A), 14424, 14673 (A), 14800; *Degener and Ordóñez* 13589; *Gillespie* 3286, 3375 (Bish), 3586, 3801 (UC), 3899, 3901 (Bish, UC), 4131 (UC); *Greenwood* 361 (Bri), 362 (Bri, K); *E. in Thurn* 58 (type coll.; BM, K); *Parks* 20505 (UC); *Totbill* 388 (K). Vanua Levu: *A. C. Smith* 697 (type coll. *A. Smithii*; fl.; GH, NY, UC, US), 711, 1722, 1758. Ovalau: *Gillespie* 4428 (UC).

Samoa.—Tutuila: *Christophersen* 1061.

VERNACULAR NAMES. — *Ndrengandrenga*, *Relese*, *Soroua*.

Type of *A. Smithii*.—“Vanua Levu: Thakauandrove, summit of Mount Mbatini, in dense thickets, alt. 1,030 m., Nov. 29, 1933, *Smith* 697 (Type), 711.” *A. C. Smith* (in herb.) queries whether *A. Smithii* is distinct from *A. montana*. The form of authority-citation accepted here for the former is debatable in different interpretations of Art. 48 of the

International Rules. In my understanding, however, the responsibility for the publication of *A. Smithii* rests almost entirely on Markgraf who named and described the plant and who treated the Apocynaceae in Smith’s article entitled *Fijian Plant Studies*.

32a. *Alstonia montana* var. *filiformis* Monachino, var. nov.

A forma typica speciei floribus minoribus, calicibus 1–1.3 mm. latis, et ramulis inflorescentiae filiformibus recedit.

Leaf blades becoming more coriaceous than in the typical form, the lateral nerves more numerous and closer, mostly 16–22 pairs, 4–6 mm. apart. Inflorescence with filiform spreading branches and pedicels; calyx 1–1.3 mm. in diameter below lobes; corolla tube 2.5–4 mm. long; corolla lobes 2–5 mm. long, pilose at base or sparsely so on the entire face within.

TYPE.—*J. Horne* 1043, Fiji Islands, June 1878. “Small tree 15–20 feet in height. Flowers yellow, small. Common in the woods at Nabesi, Suva, Viti Levu.” (Kew.)

DISTRIBUTION.—Throughout Fiji. Reported from margins of woods or woods, mountains up to 300 m. altitude; said to be “common on the poorest as well as on the richest soils, in sheltered as well as in exposed places.”

Fiji.—*Horne* 587 (fl.; GH), 607 (fl. and fr.; K); *Storck* 3 (fl. and fr.; GH, K, NY), 20 (fl. and fr.; GH, K). Viti Levu: *Horne* 861 (fl. and fr.; GH, K), 1043 (type coll.; fl.; GH, K), 1057 (fr.; GH); *MacDaniels* 1150 (Suva; A, det.?.; fl. larger, approaching typical form); *Totbill* 396 and 427 and F475 (Bish; det.?). Vanua Levu: *Milne* 213 and 215 and 261 (K), *A. C. Smith* 1540 (det.?). Naviti Levu: *Milne* 101 (fr.; K). Ovalu: *Gillespie* 4549 (fl.; Bish, UC).

This variety approaches very closely *A. Lenormandi* of New Caledonia.

*J. Horne* (1881) refers to 861 as a new species. He presents an interesting discussion on forms of *Alstonia* found in Fiji. There is a large-leaved form growing in rich soil at the bottom of valleys and ravines; this attains a

height of 30 feet and a trunk 1 foot in diameter. A small-leaved form grows on tops of ridges; this seldom attains 15 feet in height and a trunk  $\frac{1}{2}$  foot in diameter. There is also a form occupying a middle position in regard to character and habitat; this grows on the sides of ravines. Horne suggests that characters vary according to habitat.

33. *Alstonia costata* (Forst. f.) R. Br., in Mem. Wern. Soc. 1: 77. 1811. Non ex Wall. Num. List 1649. 1829; nec Wall. ex Miquel, Fl. Ind. Bat. 2: 439. 1856. = *A. macrophylla*.

*Echites costata* Forst. f., Prod. 20. 1786; non cit. "*Kametti-valli*" Rheede.

*Alstonia fragrans* J. W. Moore, in Bernice P. Bishop Mus., Bul., Honolulu, 102: 39. 1933.

?*A. elliptica* J. W. Moore, in Bernice P. Bishop Mus., Bul., Honolulu, 102: 39. 1933.

Petioles 2.5 cm. long; leaf blades very variable in shape and size, broadly elliptic to narrowly lanceolate, 9–21 cm. long, 1.5–10 cm. broad, usually sharply and abruptly long-acuminate at apex, glabrous, shining above, the lateral nerves 10–17 pairs, 8–20 mm. apart. Inflorescence mostly many-flowered; calyx 1.2–2 mm. diam. below lobes; calyx lobes ovate-lanceolate, 2–2.9 mm. long; corolla tube 3.4–4.1 mm. long; corolla lobes linear-lanceolate, 7–10 mm. long, usually pilose at base within only. Follicles 6–20 cm. long; seeds 4.5–7 mm. long, the tails short, 1–3 mm. long, their forks close to body of seed.

TYPE.—"*Echites costata* Forst. Prod., n. 123. Hab. in insulis Otaheité et Ulaitea, inter jugamontium (insularibus Attané nuncupata). Josephus Banks Baronettus. (v.s. in Herb. Banks)."

Type of *Echites costata*.—Number 123 of Forst. Prod., p. 20. "Insulae Societatis." Forster's citation of *Kametti-valli* Rheede. (Hort. Malab. 9: 23, t. 14) for his plant is erroneous, as pointed out by Robert Brown. Van Draakenstein refers *Kametti-valli* to *Aganosma*. An

amplified description of Forster's plant under *Alstonia costata* appears in Guillemain (1837: 246), in which credit is given to "Forst. mss."

ILLUSTRATIONS.—Drake, Ill. Fl. Ins. Pacif. (1886) t. 10 (leafy br., infl., fr., fl. analysis, seed).

DISTRIBUTION.—The easternmost range of the genus; in the Pacific, from Cook Islands to the Marquesas. Reported from mountain-side and forest in cloud zone; on decomposed lava and heavy clay loam; altitude 200–2,000 m.

Cook Islands.—Rarotonga: *Wilder* 544 (Bish), 729 (Bish, NY).

Society Islands.—Tahiti: *Forster* (type coll.?; fl.; K); *Lépine* 199 (G); *MacDaniels* 1542 and 1666 (Bish); *McComish* (Bri); *Moerenhout* (G); *Nadeaud* 371 (G); *Quayle* 57 and 247 (Bish); *Whitney Exped.* 588 (Bish); *Wilkes* (GH); *Setchell and Parks* 485 (GH), 525 (UC). Raiatea: *Moore* 84 (type *A. fragrans*; fl. and fr.; Min), 395 (Bish), 746 (type *A. elliptica*; fl. and fr.; Min; det.?). Eimeo (Moorea): *Wilkes* (US).

Marquesas.—Hiva Oa: *Adamson and Mumford* 140 (Bish), 498; *F.B.H. Brown* 879 (Bish); *Quayle* 1338 (Bish). Uahuka: *Quayle* 1753 and 1836 (Bish).

VERNACULAR NAMES.—Tahiti: *Afairetou*, *Atae*, *Latai*, *Napan*, *Utureva*.

Type of *A. fragrans*.—J. W. Moore "Field number 84, Sept. 16, 1926, alt. 350 m.; south facing slope of mountain, east path to Mount Temehani."

Type of *A. elliptica*.—J. W. Moore "Field number 746, Apr. 16, 1927, alt. 600 m.; in red clay soil, Red Temehani."

*A. fragrans* is placed satisfactorily under synonymy of *A. costata*. The leaf character of *A. elliptica* approaches that of *A. montana*, but the species probably is merely an atypical form of *A. costata*. *Brown* 879, from the Marquesas, has been designated by Grant (in herb.) as type of a new species; this plant, together with the other Marquesan representatives, is not completely congruous with typical *A. costata*, as already noted by F. B. H. Brown. The flowers



are stouter, calyx broader, corolla lobes broader and relatively shorter; the seeds (up to 10 mm. long) and tails (up to 3 mm. long) are longer. The difference, however, is not substantial enough to permit any segregation without further validation. F. B. H. Brown (1935: 233) stated that he observed *A. costata* in the Marquesas only at high altitudes in the rain forest and that it was never more than 2 m. in height.

34. *Alstonia Deplanchei* van Heurck & Muell.

Arg., in Flora 53: 171. 1870.—excl. cit. 462.

*Alstonia retusa* S. Moore, in Jour. Linn. Soc., Bot., 45: 363. 1921.

Petioles 0.5–1 cm. long; leaf blades oblanceolate, 3–4.5 cm. long, 1–2 cm. broad, retuse at apex, glabrous, the lateral nerves ascending, about 14 pairs, 2–3 mm. apart. Inflorescence short, sparsely flowered, the branches rather erect; corolla tube about 6 mm. long; corolla lobes oblong, about 2.5 mm. long, very faintly pubescent outside with short adpressed hairs, pilose toward base within; stamens inserted at about one-third from base of corolla tube. Follicles about 5 cm. long; seeds 7 mm. long, the tails very short, their forks close to body of seed.

TYPE.—*Deplanche* 462 *bis*, New Caledonia, Pum.

New Caledonia.—*Compton* 2363 (type *A. retusa*; photo); *Deplanche* 462 *bis* (type coll.; fl. and fr.; BM, G, L, NY).

Under *A. Deplanchei*, "*Deplanche* 462, 462 *bis*" were originally cited. The former specimen belongs with *A. Lenormandi*, but the description is obviously of the latter: "folia numerosa . . . cuneato-obovatis . . . emarginato-retusis . . . cymis parvis contractis subpaucifloris . . . tubus corollae 5 mm. longis . . . lobis tubo  $2\frac{1}{2}$ -plo brevioribus . . . corollae tubo fere ad trientem altitudinis paulo latere et staminigero . . ." In van Heurck (1871: 180) *A. Deplanchei* is clearly distinguished from *A. Lenormandi*. As the two elements represented by *Deplanche* 462 and 462 *bis* are not entirely discordant, and particularly since the original

description of *A. Deplanchei* unmistakably typifies the species, I do not reject the name as a *nomen confusum*.

Type of *A. retusa*.—"Poume: serpentine scrub; 500 ft., 2363" R. H. *Compton*, New Caledonia. Only photo of type seen, but it appears identical with type of *A. Deplanchei*.

35. *Alstonia Lenormandi* van Heurck & Muell. Arg., in Flora 53: 172. 1870.

*A. filipes* Schltr. ex Guillaumin, in Ann. Mus. Col. Marseille, Ser. 2, 9: 195. 1911.—nom. nud.

Branchlets slender; petioles 1–2(–6) cm. long; leaf blades 5–8(–18) cm. long, 2.5–5(–11) cm. broad, rounded or slightly retuse at apex, glabrous, the lateral nerves horizontally spreading, 22–25(–30) pairs, about 5 mm. apart. Inflorescence with slender peduncles, branches filiform and spreading, pedicels slender; calyx minute, 0.7–1.4 mm. diam. below lobes; calyx lobes 0.6–1 mm. long; corolla tube 2.3–3 mm. long; corolla lobes narrowly lanceolate to oblong-lanceolate, 2.8–5 mm. long, pubescent toward base within; anthers 0.7–0.8 mm. long; style short, 0.25–0.5 mm. long. Follicles 6–9 cm. long; seeds 6–12 mm. long, the tails short, their forks close to body of seed.

TYPE.—"Nova Caledonia ad Kanala, baie d'Urville, ubi legit oculatissimus Vieillard 919, et unde communicavimus amicissimus Lenormand. (in herb. van Heurck)."

DISTRIBUTION.—New Caledonia; reported as frequent in serpentine scrub, altitude 150 m.

New Caledonia: *Compton* 883 (Baie Kua-kué; BM; approaches var. *coriacea*); *Deplanche* 462 (Port-Boisé; fl. and fr.; G, K, L), 919 (type coll.; fl. and fr.; G, GH, L, NY); *Franc* 235 (serie A; Prony; type coll. *A. filipes*; fl.; A, G, GH, K, L, NY, UC, US), 2214 (fl. atypical, corolla lobes short and broad; UC); *Gandoger* (Prony; Mo); *Vieillard* 2947 (Gatope; K).

Type of *A. filipes*.—Guillaumin cited *Franc* 235. Several different collections annotated as *A. filipes* by Schlechter are available.

*Franc 2214* has leaves up to 16 cm. long and 8.5 cm. broad, but has also on the same branch much smaller leaves (7 cm. long and 3 cm. broad).

There is no precise demarcation between this species and the following two varieties.

35a. *Alstonia Lenormandi* var. *coriacea* (Panch. ex S. Moore) Monachino, stat. nov.

*Alstonia coriacea* Panch. ex Guillaumin, in Ann. Mus. Col. Marseille, Ser. 2, 9: 195. 1911.—nom. nud.

*Alstonia coriacea* Panch. ex S. Moore, in Jour. Linn. Soc., Bot., 45: 362. 1921.

Leaf blades coriaceous, lanceolate to elliptic, 7–14 cm. long, 1.5–4 cm. broad, obtuse to faintly acuminate at apex, reticulation of veins not showing.

TYPE.—“Vieillard 2956,” New Caledonia. Guillaumin, in Ann. Mus. Col. Marseille, cites “Nouvelle-Caledonie (Vieillard 2943, 2956), Boulari (Pancher 271).”

DISTRIBUTION.—New Caledonia; reported as common in scrubby woods, altitude 660 m.

New Caledonia.—*Compton 314* (Plaine des lacs; BM), 693 (Mt. Dore; BM); *Franc* (fr.; UC), 1690, 1809 (Prony; G), 1999 (Dumbea; approaches *A. Legouixiae*; G), 2473 (A); *Vieillard 914* (Unia; K), 2946 (Gatope; K).

The binomial *Alstonia coriacea* was proposed in manuscript but not published by Pancher, and was subsequently validly published and ascribed to him by S. Moore who supplied the description. In Moore's article (1921: 362) the citation of authority appears as “Panch. MS. ex Guillaum.”

35b. *Alstonia Lenormandi* var. *lanceolifera* (S. Moore) Monachino, stat. nov.

*Alstonia lanceolifera* S. Moore, in Jour. Linn. Soc., Bot., 45: 362. 1921.

Corolla lobes broadly ovate, 2.2–2.4 mm. long, 2.2–2.8 mm. broad, obtuse at apex. Leaves in *Franc 224* are similar to those of *A. Lenormandi* var. *coriacea*; in type (ex descrip. and photo): mostly opposite, rarely ternately ver-

ticillate; petioles about 5–10 mm. long; leaf blades, pergameneous, oblong-lanceolate, 8.5–10.5 cm. long, 1.7–2.5 cm. broad, the lateral nerves 20–24 pairs.

TYPE.—“Mt. Koghi; margin of valley forest; 1000 ft.; serpentine. 766” *R. H. Compton*, New Caledonia.

New Caledonia.—*Compton 766* (type; photo); *Franc 224* (Dumbea; A, G, L, NY, UC, US).

Moore notes, “This has much the foliage of *A. lanceolata* v. *Heurck & Müll. Arg.*, but different flowers.”

36. *Alstonia Legouixiae* van Heurck & Muell. Arg., in *Flora* 53: 171. 1870.

Leaves very similar to those of *A. Lenormandi* var. *coriacea* but generally ternately verticillate as well as opposite; petioles somewhat shorter, 0.5–1 cm. long; leaf blade 5–7 cm. long, 1–2 cm. broad, the lateral nerves obscure. Inflorescence with ascending branches stouter than those of *A. Lenormandi*, flowers numerous and in rather crowded cymes; calyx 1–1.6 mm. diam. below lobes; calyx lobes 0.9–1.3 mm. long; anthers 0.8–1.2 mm. long; corolla and seeds like those of *A. Lenormandi*; follicles 3–10 cm. long.

TYPE.—“ad laterd arida montium in Sinu Tupiti insulae Novae Caledoniae: *Vieillard 920* (in herb. van Heurck).”

DISTRIBUTION.—New Caledonia; reported as frequent, altitude 100–1,000 m.

New Caledonia.—*Compton 738* (Mt. Koghi; BM), 1324 (Bogota; BM), 2030 (Nekando; BM); *Franc 63* (Prony; G), 522 *bis* (Mt. Dzumae; L), 2317 (Mt. Koghi; A); *Pancher 272* (K); *Schlechter 15182* (Ngoyé; G, L, K); *Vieillard 2942* (Kanala; BM, F).

“*Alyxia Legouixiae*” in Guillaumin (1911a: 196) is a typographical error for *Alstonia Legouixiae*.

37. *Alstonia saligna* S. Moore, in Jour. Linn. Soc., Bot., 45: 364. 1921.

Shrub or small tree, the branchlets slender; petioles short, 0.5–1 cm. long; leaf blades thinly



coriaceous, linear-lanceolate, 5–9 cm. long, about 0.5–0.8 cm. broad, blunt at apex, glabrous, the lateral nerves about 30 pairs. Inflorescence lax, branches divaricate, pedicels about 6 mm. long; calyx 1.25 mm. long; corolla tube 2.25 mm. long; corolla lobes oblong, 4 mm. long; anthers 0.3 mm. long. (Compiled from original description and photograph.)

TYPE.—"Riv. Ngoyé; *Spermolepsis-Casuarina* forest; 500 ft.; serpentine. 1009." *R. H. Compton*, New Caledonia. (British Museum.)

SPECIMEN EXAMINED.—Type (photo).

The available data on *A. saligna* are not sufficient to place the species precisely. Affinity with *A. Lenormandi* is suggested. Moore notes, "In the flowers this much resembles *A. Comptonii*, but its smaller narrow willow-like leaves are very distinct."

38. *Alstonia Comptonii* S. Moore, in Jour. Linn. Soc., Bot., 45: 363. 1921.

Small tree up to 7 m. high; branches stout; leaves opposite; petioles 1.5–5 cm. long; leaf blades thinly coriaceous, oblong-oblancoate, large, 12–25 cm. long, 3–6 cm. broad, rounded to shortly blunt-acuminate at apex, glabrous, the lateral nerves numerous, 35–50 pairs. Inflorescence ample, lax, and diffuse, the branches greatly divaricate, the pedicels long and slender, about 4 mm. long; corolla tube 2.25 mm. long; corolla lobes 4 mm. long; anthers 0.75 mm. long. (Compiled from original description and photograph.)

TYPE.—"Kuakué; scrub-forest; 200 ft.; serpentine. 953." *R. H. Compton*, New Caledonia. (British Museum.)

Moore notes, "The long narrow *Rauwolfia*-like leaves coupled with the very divaricate branches of the cymes affords an easy means of recognizing this plant."

#### SECTION DOUBTFUL

39. *Alstonia quaternata* van Heurck & Muell. Arg., in Flora 53: 170. 1870.

Branchlets stout (7–15 mm. diam.); leaves

4-verticillate; petioles 2–4.5 cm. long; leaf blades elliptic, 8–16 cm. long, 2.5–4 cm. broad, rounded or obtuse at apex, gradually and strongly attenuate at base, glabrous, strikingly nitidous above, the margins involute, the lateral nerves horizontally spreading, rather straight, 35–60 pairs, 1.5–3 mm. apart, the reticulation not manifest. Inflorescence closely crowded, the ultimate branches adpressed or ascending, profusely bracteate (bracts deciduous), the pedicels very short; calyx lobes carnosae, ovate, about 1.3 mm. long and 1.6 mm. broad, obtuse at apex, entirely glabrous; corolla tube 5–5.4 mm. long, glabrous outside; corolla lobes very thick, cucullate, oblong, 2.8–4.1 mm. long, 1.7 mm. broad, glabrous without, pilose within the lower half and bearded at base; anthers 1.2–1.4 mm. long, the filaments inserted at about one-third from base of corolla tube; style very short or not apparent; ovary characteristically sulcate longitudinally with about 10 sharp ridges, glabrous, (either of two carpels very close together or syncarpous); ovules in two rows (sometimes reduced to one row?) in each cell, relatively few.

TYPE.—"Nova Caledonia ad Ponébo: *Deplanche* 456 (in herb. van Heurck)."

New Caledonia.—*Deplanche* 456 (type coll.; fl.; G, K); *Schlechter* 15578 (mt. near Oubatche; fl.; G, GH, K, L).

This interesting species is outstandingly unique and cannot be placed satisfactorily in any section. It suggests § *Dissuraspermum*, affinity with *A. Legouixiae*. Discovery of the fruits should clarify its position.

#### DOUBTFUL SPECIES

*A. angustifolia* var. *latifolia*: see *A. angustifolia*.

*A. elliptica*: see *A. costata*.

*Alstonia Godeffroyi* Reinecke, in Engl. Jahrb. 25: 667. 1898. Type.—"Upolu: Letogo-Siuma-Kamm, 750 m. Apr. 1895 (483)" Reinecke, Samoa. Belongs to § *Dissuraspermum*, but without the type I am unable to sug-

gest its precise position. The salient features in its original description are as follows: petioles 2–3 cm. long; leaf blades narrowly long-lanceolate, 12–20 cm. long, 1.5–3 cm. broad, glabrous; cymes many flowered; corolla tube 1.5–2 mm. long; corolla lobes 3–4 mm. long; follicles 15–25 cm. long. Of the *Alstonia* specimens examined the only species I accredit to Samoa are *A. Reineckea*, *A. Setchelliana*, and *A. montana*. The leaf shape of *A. Reineckea* is variable and it is not impossible that examples can be found like that of *A. Godeffroyi*. Examples are available of narrowly lanceolate leaves in *A. costata*; this species, however, has not yet been collected west of the Cook Islands.

"*Alstonia intercedens*" in van Heurck, Obs. Bot. 176. 1871.—*nom. nud.* Appears in the discussion under *A. quaternata*, likely through error.

*A. Kurzii*: see *A. scholaris*.

*A. longissima*: see *A. spectabilis*.

*A. paucinervia*: see *A. macrophylla*.

*Alstonia pedicellata* Pierre ex A. Cheval., Veg. Ut. Afr. Trop. Franc. 9: 273. 1917.—pro synon. Chevalier cited this name, ex Pierre MS., in synonymy under *A. congensis*. However, Chevalier's concept of *A. congensis* is questionable as he distributed specimens of *A. Boonei* under this name (*Chevalier* 2690 and 15194).

*A. Setchelliana*: see *A. Reineckea*.

*Alstonia spectabilis* var. *bantamensis* Blume, Bijdr. Fl. Ned. Ind. 16: 1037. 1826. Type.—"montanis Provinciae Bantam." I am uncertain about Blume's concept of *A. spectabilis*. His description of the leaves being in verticils of 4–6 suggests a form of *A. scholaris*, or possibly *A. angustiloba*, rather than *A. spectabilis*. The diagnosis given by Blume for his variety is: "foliis cuneato-oblongis obtusiusculis, umbella terminali simplicis." It is unlikely that the variety refers to *A. spatulata*, as this species was known to Blume, who was its author.

*Alstonia viscosa* K. Schum. ex. Engl., in Sitz. Preuss. Akad. Wiss. 38: 829. 1908.—*nom. nud.* Listed without description or any

other reference by A. Engler, *Pflanzengeographische Gliederung von Africa*, under the section dealing with the Congo basin and the area where Pogge collected in 1883. There are only two species of *Alstonia* known from Africa, namely *A. congensis* and *A. Boonei*.

*A. villosa* f. *calvescens*: see *A. spectabilis*.

## EXCLUDED SPECIES

*Alstonia ciliata* Benth., Pl. Hartweg. 48. 1840. Type.—"In loco Banco dicto," Hartweg 366, Mexico. ( ! type coll.; sterile; G.) Corrected by Benthham in the same work (1841) to *Symplocos*. The species is placed by A. Brand (1901: 80) under *Symplocos coccinea* var. *Benthhamii* (Gürke) Brand.

*Alstonia costulata* Miquel, Fl. Ind. Bat. Suppl. 556. 1860. Type.—"Sumatra occid. in prov. Priaman (*Diepenhorst*)."  
=*Dyera costulata* (Miquel) Hook. f.

*Alstonia edulis* G. Benn., in Jour. Bot. 5: 150. 1867. George Bennett received the fruits of this species from D. N. Joubert, who brought them from New Caledonia and also gave information regarding them. The species is said to be a climbing plant growing most luxuriantly in all the thick scrubs along the banks of freshwater streams; leaves heart-shaped, of a dark-green color; fruits in clusters, downy skinned, and exuding a milky juice. The natives in the vicinity of Port de France call it *Jecko*, and use it as food. Some of the fruits were cooked by Bennett, who found them "of an agreeable flavor." Bennett's reference to this plant is very casual, and no mention is made of it by subsequent authors, except Guillaumin (1911a: 195), who cites "*A. edulis* G. Benn.—Nouméa (*Vieillard*)."  
There are no vines in *Alstonia*, and no known species in the genus has cordate leaves. Obviously, *A. edulis* is not an *Alstonia*.

*Alstonia eximia* Miquel, Fl. Ind. Bat. Suppl. 555. 1860. Type.—"Bangka, prope Djebus (*Teysmann*)."  
( ! L ) = *Dyera costulata* (Miquel) Hook. f.



*Alstonia ficifolia* S. Moore, in Jour. Bot. 61 (Suppl.): 32. 1923. Specimen examined.—type coll., *Forbes* 74, Sogere, New Guinea (fl.; K). Markgraf (1927: 190) has correctly named the species *Ochrosia ficifolia* (S. Moore). Flowering and fruiting specimens of an *Ochrosia* deposited at the New York Botanical Garden, C. E. Carr 12615 and 12616, collected at Koitaki, Papua, belong either to this species or to an undescribed one bearing very close affinity to it (the calyces, 4 mm. broad, are broader than those seen in *Forbes* 74). Of the flowering material, only two buds in poor condition were available. The fruits, hitherto unknown for *O. ficifolia*, are ellipsoid, not angled, 8 cm. long, 4 cm. in diameter, their mesocarp is hard-woody and of a rather uniform texture except for deep pits near the surface. The tree is noted as about 60 feet tall and as bearing copious latex. As further indications of the sometimes similar appearance of *Ochrosia* and *Alstonia* are two sterile specimens collected in Netherlands New Guinea, Seroei, Japan (*Neth. Ind. For. Serv.* 30273 and 30288; A). These match the Koitaki plant and have been distributed as "*Alstonia* sp. nov."

*Alstonia grandifolia* Miquel, Fl. Ind. Bat. Suppl. 555. 1860. Type.—"Sumatra orient. in prov. Palembang (*Teysmann*). " (! K, L) = *Dyera costulata* (Miquel) Hook. f.

*Alstonia longifolia* (A. DC.) Pichon, in Paris Mus. d'Hist. Nat. Bul., II, 19: 297. 1947. = *Tonduzia longifolia* A. DC. See discussion in Supplement.

*Alstonia lucida* D. Don, Prod. Fl. Nepal. 131. 1825. *Blaberopus lucidus* A. DC., Prod. 8: 411. 1844. Type.—"Nepalia. Hamilton. Wallich. *Echites triangularis* Hamilton Mss." The reference to Wallich seems to be to No. 1675 (!), "*Ichnocarpus fragrans* Wall." of the Numerical List, which is *Trachelospermum lucidum* (D. Don) K. Schum. *A. lucida* is placed under *Trachelospermum* by Hooker, Woodson, Tsiang, and others.

*Alstonia micrantha* Ridley, Jour. As. Soc. Straits 79: 95. 1918. Type.—"Selangor; Rantau Panjang (*Kloss*). " (! K) = *Chilocarpus*, possibly *C. embelioides* King & Gamble (ex descrip.).

*Alstonia polyphylla* Miquel, Fl. Ind. Bat. Suppl. 556. 1860. Type.—"Bangka (*Teysmann*). " = ? *Dyera Lowii* Hook. f. (1882).

*Alstonia Schumanniana* Schlechter, in Bot. Jahrb. 39: 236. 1906.—descrip; Pflanzengeograph. Glied. Insel Neu-Caled. 37. 1904.—*nom. nud.* Type.—"Bei Oubatche. 15442" Schlechter, New Caledonia. (! G, K, L) = *Rauvolfia*.

*Alstonia theaeformis* L.f. = *Symplocos* (see discussion under *Alstonia*).

"*Alstonia* sp. nov." Schlechter, in Bot. Jahrb. 39: 236. 1906. *Schlechter* 15651 (New Caledonia, "Bergen bei Ou-Hinna"; BM, K). Not *Alstonia*; apparently Rubiaceae. Not adequate for specific identification without comparative material. Suggests description of the monotypic genus *Merismostigma* S. Moore (1921: 332).

## SUPPLEMENT

While my manuscript was in the editor's hands, M. Pichon's recent (1947) treatise on *Alstonia* became available to me. Except for inserts in the synonymy citations in my original manuscript, the matter in this excellent paper was not treated. A very brief account of the important features in Pichon's article will be given here.

The most interesting discovery made by M. Pichon is the close similarity between *Alstonia*, which had hitherto been given exclusively an Old World distribution-range, and the New World *Tonduzia* Pittier (Central America and southern Mexico). Can it be that *Alstonia*, which in the Pacific is known as far east as the Marquesas and which extends as far west as Sierra Leone in Africa, has bridged the remaining oceanic areas and encircles the entire earth?

Pichon gives *Tonduzia* a sectional status next to § *Pala*. In *Tonduzia* the leaves are usually

3- or 4-verticillate, pointed at the apex, and have close lateral nerves; the left margins of the corolla lobes overlap, and the follicles are apocarpous. At first sight, *Tonduzia* might suggest an anomalous species in § *Dissuraspermum*, with contrariwise aestivation. This impression is particularly supported by its apparent seed character. The seeds of *Tonduzia longifolia* (A. DC.) Markgraf superficially resemble those of *Alstonia constricta*, except that they are glabrous on the sides. They are elliptic, about 10 mm. long and 3 mm. broad, somewhat erose at one end, and with a short (about 2 mm. long) bifurcate tail at the other end. These seeds appear ciliate along the margins in the manner of § *Dissuraspermum*. But when examined closely the seeds of *Tonduzia* are found to be not at all ciliate with simple distinct hairs as in *Alstonia*. Instead they are surrounded by a membranous border which is finely and repeatedly lacerate. Principally because of this difference in the actual morphology of the seeds in the two genera, I judge it best to maintain *Tonduzia* separate from *Alstonia*.

In proposing that *Blaberopus* A. DC. be returned to generic status, in which category it was held by some of the older botanists, Pichon has selected the section of *Alstonia* most deserving of such rank. I have already noted this in my comments under the synonymy of *Alstonia*, and my continuing to give *Blaberopus* sectional rather than generic rank is largely a matter of personal inclination. The differences between the sections *Pala* and *Blaberopus* are admittedly great, but are they of generic magnitude? If considered so, what shall be the disposition of *Dissuraspermum*, a section which also presents great divergences from *Pala*?

*Winchia* is also accepted as a genus by Pichon. There is little in favor of this. In fact, it might be argued with considerable reason that *Winchia* be altogether submerged into the § *Pala*.

*Paladelphina* Pichon was typified by *Alstonia angustiloba*, which is here placed in § *Pala*. The characters stressed by Pichon in segregating the

new genus are the narrow anthers, 2-pored compressed pollen, the ovary provided with some hairs, and the clavuncle slender, glabrous, with spreading collar. I find the flowers of *A. pneumatophora* hardly distinguishable from those of *A. angustiloba*. The leaves of the former resemble closely those of *A. spatulata*. These three species bear unmistakable affinity with *A. scholaris*, the type of the § *Pala*. The indumentum is often lacking (*A. angustiloba* var. *glabra*) on the ovary of *A. angustiloba*.

Pichon proposes two series, *Glabrae* and *Pilosae*, under § *Pala*. In the series *Glabrae*, *A. spatulata* and *A. sericea* are cited as species studied, and *A. pachycarpa* as seen but without flowers. The last species belongs in § *Winchia*, whereas *A. sericea* is most probably a synonym of *A. neriifolia* in the § *Blaberopus*. In the series *Pilosae*, Pichon cites as studied *A. Gilletii*, *A. congensis*, and *A. scholaris*. The first species listed is *A. congensis*, and the second very likely *A. Boonei*. The two series are represented by primary subdivisions in my key to the species in § *Pala*. I do not believe they merit formal names.

Also, Pichon proposes two series under § *Dissuraspermum*. His series *Occidentales* corresponds largely to the § *Monuraspermum* already presented in my original manuscript. *A. constricta*, which Pichon cites as one of the species studied for the series, more properly belongs in § *Dissuraspermum* than in § *Monuraspermum*. Of the species noted as seen but not studied in this series, *A. grandifolia* belongs with *Dyera costulata*, and *A. pneumatophora* in § *Pala*. The series *Orientales* is typical § *Dissuraspermum*.

Finally, Pichon (1947: 298) attributes to Guillaumin four *Alstonia* species, of which I have seen neither specimen nor description or any other reference. These are: *A. Balansae*, *A. linearifolia*, *A. stenophylla*, and *A. undulata*. These species do not appear under *Alstonia* in the Kew Index up to the 1940 Supplement. It is quite probable, however, that Pichon, in the



Laboratoire de Phanérogamie du Muséum, Paris, had access to literature not available to me. He notes that he studied these species, which he places in § *Dissuraspermum*. Therefore, Pichon must have had actual material of these species on hand.

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# NOTES

## Research Openings in Micronesia

The following announcement has been received from Harold J. Coolidge, Executive Secretary, Pacific Science Board of the National Research Council:

As a result of a grant from the Office of Naval Research to the National Research Council, the following research openings will be available in the Trust Territory after 1 April 1949 for work in the fields indicated. Applications at a pre-doctoral and post-doctoral level showing previous field experience, academic background, and special field of interest, together with a detailed description of the proposed project on which the applicant wishes to perform his research should be addressed to the Pacific Science Office prior to 1 April 1949.<sup>1</sup>

- 2 Anthropologists (Archeology, Physical Anthropology, Linguistics)
- 2 Botanists
- 1 Geographer (Human or Economic)
- 1 Medical Researcher (Hypertension or Parasitology)
- 1 Nutrition Researcher
- 3 Zoologists (1 in Entomology)

The time in the field for these research openings will vary from 4 to 5 months and there will be a salary supplement ranging from \$100

<sup>1</sup>By permission, mention of this note will secure consideration of applications received a reasonable time after April 1, 1949.—Ed.

to \$400 per month depending on the qualifications of the applicant.

Each researcher will be furnished with transportation funds to assist with expenses to and from the U. S. Port of Embarkation. The Navy will furnish the necessary transportation from the Pacific Coast to the field and return. The Board plans that \$100 per month will be allocated to each scientist to cover living expenses in the field, BOQ, subsistence, and native assistance.

In certain cases a Final Comprehensive Report covering research accomplished in the field will be required, and a payment of \$100 will be made upon acceptance of this Report.

This is an unusual opportunity for a limited number of scientists desiring to broaden their experience through field research in a little known area.

Previously it has been customary for participants in this type of research to be assisted and sponsored by a University or an Institution with which they are associated, and which has often helped in providing collecting equipment and other types of assistance. This is the most favorable arrangement, but direct contracts with individual scientists are also possible.

## Prevention of Deterioration Abstracts

The National Research Council of the National Academy of Sciences (Prevention of Deterioration Center, Room 204), 2101 Constitution Avenue, Washington, D. C., offers the *Prevention of Deterioration Abstracts* on a yearly subscription basis. These Abstracts are classified under the following headings: Biological Agents; Electrical and Electronic Equipment; Fungicides and Other Toxic Compounds; Lac-

quers, Paints and Varnishes; Leather; Lubricants; Metals; Miscellaneous; Optical Instruments and Photographic Equipment; Packaging and Storage; Plastics, Resins, Rubbers, and Waxes; Textiles and Cordage; Wood and Paper. Cross references are included in each issue; author and subject indexes are compiled at the conclusion of each volume. Material for the Abstracts is obtained from journal articles, pat-

ents, and unpublished reports from government, university, and industrial research groups both here and abroad.

Approximately 2,000 pages are published a year, in two volumes of six issues each. The individual abstracts are in loose-leaf form so that they may be arranged in any manner desired by the individual receiving them. Comments are added to many of the abstracts to correlate relevant information, to evaluate reports, or to make suggestions for further research.

The yearly subscription rate, which includes two sturdy binders and index guides, is currently \$37.50. The rate will be \$50.00 for requests received after July 1, 1949. All subscriptions run from July 1st to June 30th. Back issues are available from April 1946, when the series was started.

An *Advance List*, a monthly bibliography of all the reports received in this field by the Prevention of Deterioration Center, is also available for an additional \$10.00 per year.

## News Notes

Dr. Carl L. Hubbs of the Scripps Institution of Oceanography, University of California, La Jolla, California, delivered an address entitled "Hybridization between Fish Species in Nature" to an open meeting of the University of Hawaii chapter of Sigma Xi on January 27, 1949.

Elwood C. Zimmerman's five-volume work *Insects of Hawaii* (University of Hawaii Press) was awarded the \$250 prize for "the most distinguished book by a resident of Hawaii published during the previous year." This award is made annually by the Friends of the Library, an organization associated with the Library of Hawaii, Honolulu. (For an announcement of *Insects of Hawaii*, see *Pacific Science* 2(4): 301.)

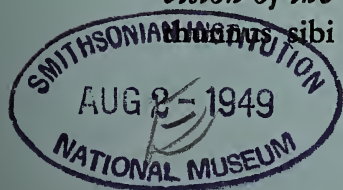


# PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



IN THIS ISSUE: White—*Finschia*—*A Genus of Nut Trees* • Bayer—*Alcyonaria from the Marshall Group* • Leopold and Stidd—*Concepts in Hawaiian Climatology* • Richardson—*Native Birds on Molokai* • Cowan—*Revision of the Genus Neraudia* • Brock—*Parasites sibi in Hawaiian Waters* • NOTES



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Contributions to Pacific biological and physical science will be welcomed from authors in all parts of the world. Manuscripts may be addressed to the Editor-in-Chief, *PACIFIC SCIENCE*, University of Hawaii, Honolulu 14, Hawaii, or to individual members of the Board of Editors. Use of air mail for sending correspondence and brief manuscripts from distant points is recommended.

Manuscripts will be acknowledged when received and will be read promptly by members of the Board of Editors or other competent critics. Authors will be notified of the decision reached as soon as possible.

Manuscripts of any length may be submitted, but it is suggested that authors inquire concerning possibilities of publication of papers of over 30 printed pages before sending their manuscript. Authors should not overlook the need for good brief papers presenting results of studies, notes and queries, communications to the editor, or other commentary.

### PREPARATION OF MANUSCRIPT

Although no manuscript will be rejected merely because it does not conform to the style of *PACIFIC SCIENCE*, it is suggested that authors follow the style recommended below and exemplified in the journal.

**Title.** Titles should be descriptive but brief. If a title runs to more than 40 characters, the author should also supply a "short title" for use as a running head.

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**Footnotes.** Footnotes should be used sparingly and never for citing references (see later). Often, foot-

[Continued on inside back cover]



A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION

NO. 3

## CONTENTS

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## *Finschia*—A Genus of "Nut" Trees of the Southwest Pacific

C. T. WHITE<sup>1</sup>

### INTRODUCTION

A PLANT FAMILY with a most interesting and intriguing distribution is Proteaceae, which finds its greatest development in Australia (650 species) on the one hand and South Africa (300 species) on the other, though the two countries have no genera in common. Practically all the South African species and the vast majority of Australian ones are markedly xerophytic. The largest genus, *Grevillea* R. Br., consists mainly of xerophytic shrubs or small trees but a few are large trees found in the rain forests of tropical and subtropical eastern Australia, New Guinea, and New Caledonia. In the southwest Pacific area the family finds its greatest development in northeastern Australia, where trees belonging to it provide the great bulk of cabinet timbers known in the trade as "Silky Oaks." There is close affinity between the Proteaceae of eastern Australia and of western South America as illustrated by the genera *Embothrium* Forst. which has four species in South America, two in Australia, and one in New Guinea, and *Lomatia* R. Br. which has four species in South America and eight in Australia. The endemic Australian genus *Telopea* R. Br. is separated from *Embothrium* Forst. on very slender grounds, and Diels (1916: 200), with some doubt, records the genus *Euplassa* Salisb., otherwise consisting of eight South American species, as Papuan and Australian (one species each).

An outstanding feature of the flora of the rain-forest belt of northeastern Australia is the number of monotypic or very small genera of Proteaceae developed in it, e. g., *Austromuelleria* C. T. White, *Buckinghamia* F. Muell., *Cardwellia*

F. Muell., *Carnarvonia* F. Muell., *Darlingia* F. Muell., *Hollandaea* F. Muell. (two spp.), *Musgravea* F. Muell., and *Placospermum* White & Francis. A surprising feature is the absence, with the exception of one species in New Zealand, of the family from Polynesia.

There is in the islands of the southwest Pacific—Caroline Islands, New Guinea, Solomon Islands, and the New Hebrides—a group of trees with the floral characters of *Grevillea* R. Br. and the fruit of *Helicia* Lour. These, I consider, all belong to *Finschia* Warb. This genus was founded by Warburg (1891: 297) on a tree from northeastern New Guinea. His original description would cover *Grevillea* R. Br. exactly though he does not mention this genus and on the following page the distinctions he gives for separating his proposed new genus from *Helicia* are exactly those which distinguish *Grevillea* from that genus. H. Sleumer (1939: 127), in a more recent contribution to our knowledge of Papuan Proteaceae, includes *Finschia* Warb. in *Grevillea* R. Br. and gives a key to the New Guinean species. Lauterbach (1913: 329), in a key to the Papuan genera of Proteaceae, distinguishes *Finschia* Warb. from *Grevillea* R. Br. by the fruit being scarcely dehiscent. Later Diels (1916: 205), in an account of new Papuan Proteaceae, referred to this and stated that Lauterbach's conclusions were unfounded as fruits of neither *F. rufa* Warb. nor *F. chloroxantha* Diels, the only two species so far described, were known. An emended description of the genus and a key to the species are offered here, a new species is described, and a new combination proposed.

<sup>1</sup> Government Botanist, Brisbane, Queensland, Australia. Manuscript received July 9, 1948.

**Finschia Warburg**  
(Emended description)

Flowers hermaphroditic. Petals (perianth segments) curved and united in the bud stage, soon free. Anthers sessile or nearly so within the concave laminae or tips of the petals, connective broad, not produced beyond the anther cells, anther cells slightly divergent towards the base. Torus oblique. Hypogynous gland fleshy, entire, horseshoe-shaped or nearly annular; ovary stipitate, style slender or narrowly clavate, usually long and protruding from the split on the lower side of the perianth tube in the later bud stage. Fruit an indehiscent drupe; exocarp thin, fleshy; endocarp bony, rough; cotyledons 2, thick and fleshy and filling the seed. Trees, trunk buttressed, often raised on stilt roots. Leaves entire. Inflorescence racemose, racemes axillary or on the older wood below the leaves.

Type species: *F. rufa* Warb. (1891: 297).

Four species in the rain forests of Micronesia (Caroline Islands), New Guinea, Solomon Islands, and the New Hebrides.

Key to the Species

Leaves densely rufous- or ferruginous-pubescent beneath.

- Leaves 28–35 cm. long, 11–13 (to 17) cm. wide; inflorescence to 40 cm. long . . . . . 1. *F. rufa*  
Leaves 18–25 (to 28) cm. long, 6–9 cm. broad; inflorescence 24–26 cm. long . . . . . 2. *F. Carrii*

Leaves glabrous.

- Flowers very densely ferruginous-pubescent; fruit globose, not laterally compressed, over 4 cm. diam. . . . . 3. *F. ferruginiflora*  
Flowers thinly ferruginous-pubescent in the bud stage, almost glabrous when fully developed; fruit laterally compressed, not above 4 cm. diam. . . . . 4. *F. chloroxantha*

In the following account of the species the letters B.S.I.P. and N.G.F., preceding the collectors' numbers, stand for British Solomon Islands Protectorate and New Guinea Forests, respectively. The first precedes all specimens collected in the Solomon Islands by F. S. Walker

and myself in 1945–1946 and the latter those made in New Guinea under the direction of Major J. B. McAdam, C.R.E., New Guinea Forests, by officers and men of his unit headquarters and two associated forest survey companies.

1. *Finschia rufa* Warburg (1891: 298)

*Grevillea rufa* (Warburg) Sleumer (1939: 128).

Tree. Leaves large, coriaceous, shortly petiolate, apex obtuse or rotundate, base acuminate, entire, adult leaves glabrous above, the midrib and main nerves rather prominent, rufous- or ferruginous-tomentose beneath, the midrib, lateral nerves, and the veins very prominent, lateral nerves about 20 on each side of the midrib, not markedly curved, joined below the margin and united with an intramarginal vein close to the edge; blade 25–35 cm. long, 11–13 (to 17) cm. wide; petiole 2 cm. long. Racemes 17–40 cm. long; rachis, pedicels, and flowers densely clothed with red-brown hairs (rufous-villous). Flowers solitary or in pairs, pedicels 1 mm. long; petals (perianth segments) about 1 cm. long, glabrous on the inner face; ovary stipitate, seated obliquely on a 3-mm. long stipes, style 7 mm. long; torus oblique, hypogynous gland annular or nearly so. Fruit unknown.

Northeast New Guinea: Only known from the neighbourhood of Sattelberg where, according to Sleumer, *loc. cit.*, it has been collected several times. (Warburg 20496, type: Hellwig 531, Clemens 2234 and 8094 A.)

Unfortunately I have not seen specimens and the above description is drawn from that of the author's original and from the few notes in Sleumer's key. According to Warburg, the pedicels are only 1 mm. long, which would give the inflorescence almost a spicate appearance which, apart from the larger leaves, should distinguish it from the next species.

2. *Finschia Carrii* (Sleumer) C. T. White  
*comb. nov.*

*Grevillea Carrii* Sleumer (1939: 128).

Tree, about 12 m. high, branchlets densely





FIG. 1. *Finschia ferruginiflora* C. T. White. New Guinea: L. S. Smith 1093 (flowers) and 1060 (fruits). A, flower (slightly enlarged); B, gynaecium (slightly enlarged); C, fruit.



rufous- or ferruginous-pubescent. Leaves narrowly obovate, apex rounded, base cuneate, chartaceous, glabrous above except for the midrib; lateral nerves from 14 in the smaller leaves to 24 in the larger ones on each side of the midrib, united to form a strong intramarginal vein 4–5 mm. from the edge with a finer less distinct one very close to the margin, slightly raised, connecting veins and veinlets clearly discernible in the dried specimens, densely rufous- or ferruginous-pubescent beneath, lateral nerves and connecting and reticulate veinlets raised and prominent; blade 13–28 cm. long, 6–9 cm. wide, petiole densely tomentose, 1.5–3 cm. long. Racemes mostly on the older wood below the leaves, very densely flowered, 24–30 cm. long including the short peduncle; rachis, pedicels, and flowers densely rufous- or ferruginous-tomentose; pedicels in pairs, slender, 4–5 mm. long. Petals (perianth segments) 7–8 mm. long, glabrous on the inner face, ovary densely clothed with rather long reddish hairs, stipitate; stipes glabrous, style glabrous, grooved, gradually thickened towards the top; stigma pyramidal; hypogynous gland very prominent, entire, horseshoe-shaped or almost annular.

Southeast New Guinea: Koitaki, alt. ca. 1,500 ft. in rain forest, *C. E. Carr No. 12058* (fls.), April, 1935 (tree 12 m.; fls. golden-yellow, tipped brownish-orange, style bright yellow-green, stigma deep green).

Though fruits are unknown, I have transferred this to *Finschia* Warb. owing to its close relationship to *F. rufa* Warb., from which it differs chiefly in being smaller in all its parts. The description has been drawn mainly from isotype material but a few notes from Sleumer's original description have been incorporated mainly to give variation in size of leaf and a few other characters. The species is known only from the type gathering.

### 3. *Finschia ferruginiflora* sp. nov.

Fig. 1

Arbor 30 m. alt., trunco per radices adventitios ad 1.5 m. altos supra terram elevato, cortice

bruneo lenticellarum rimis notato, ramulis validis, partibus novellis ferrugineis mox glabris. Folia utrinque glabra, anguste obovata, apice rotundata, basi cuneata in petiolum validum angustata, chartacea, nervis lateralibus primariis utrinsecus 18–20, utrinque prominentibus, in venam intramarginalem 4–5 mm. a margine arcuatim confluentibus, venulis in sicco laxe reticulatis supra parum subtus distinctius elevatis; lamina 14–22 cm. longa, 3.5–5 cm. lata; petiolus 1–1.5 cm. longus. Racemi densiflori, axillares, saepe ex axillis foliorum delapsorum orti, breviter pedunculati, cum pedunculo 13–18 cm. longi, cum floribus pilis ferrugineis densissime obsiti; pedicelli graciles, ca. 1 cm. longi; torus obliquus, glandula hypogyna integra hipocrepiformi; petala (perianthii segmenta) 7–8 mm. longa; pistillum 1.2 cm. longum, ovario unilaterali fusco-piloso stipitato, stipite cum stylo glabrescenti. Fructus indehiscens, globosus, ca. 5 cm. diam., fere vel omnino sessilis, pericarpio tenui, endocarpio osseo 7–8 mm. crasso, sutura visibili sed indistincta.

Northeast New Guinea: Kuminkira, Aiyura, alt. about 5,000 ft., *L. S. Smith N.G.F. 1093* (Type: flowers) October, 1944 (tree 100 ft., with adventitious roots up to 4.5 feet above the ground; bark brownish, slightly dotted with pustular lenticels, very finely longitudinally cracked with a few small corky scaled patches; flowers rusty brown, style green with green stigma). Bracken Ridge, Aiyura, alt. about 6,000 ft., *L. S. Smith N.G.F. 1060* (fruits) October, 1944 (tree 100 ft., trunk raised on adventitious roots up to 3 feet above the ground; bark brownish with small pustular lenticels sometimes arranged in short longitudinal rows; fruits globular, brownish; seeds cooked and eaten by the natives).

### 4. *Finschia chloroxantha* Diels (1916: 204) Figs. 2, 3

*Grevillea densiflora* C. T. White (1922: 25);  
H. Sleumer (1939: 129).

*Grevillea elaeocarpifolia* Guillaum. (1932: 87).





FIG. 2. *Finschia chloroxantha* Diels. Bougainville: S. F. Kajewski 2033.



*Helicia micronesica* Kanehira (1933a: 95, fig. 23 [fol. fruct.]; 1933b: 669; 1935: 311).

*Finschia micronesica* (Kanehira) Kanehira (1938: 241, fig. 72 [fl.]).

*Finschia Waterhouseana* B. L. Burtt (1936: 465).

*Grevillea micronesi(a)ca* (Kanehira) Sleumer (1939: 129).

*Finschia densiflora* (C. T. White) C. T. White (ex Walker, 1948: 155).

Tree up to 25 m. high, trunk buttressed, often raised on stilt roots; bark grey to light brown, usually marked with pustules in longitudinal lines; young parts densely clothed with a tawny or ferruginous pubescence. Leaves lanceolate, elliptic or narrowly obovate ("oblanceolate"), apex acute or blunt, base cuneate, in the dried state dull or nitid above; main lateral nerves from about 12 on each side of the midrib in the smaller leaves to about 30 in the larger ones, arching to form an intramarginal vein, sometimes very distinct, at others not very clearly defined; blade variable in size, 9–40 cm. long, 3.5–13 cm. wide; petiole 1–2.5 cm. long. Racemes many flowered, axillary or more frequently on the older wood below the leaves, rachis pubescent, to 30 cm. long, including the comparatively short peduncle. Flowers yellow-green to orange-yellow, pedicels and petals (perianth segments) thinly clothed with a few scattered brown hairs; pedicels 0.3–1 cm. long; petals 0.4–0.8 cm. long. Ovary glabrous, stipitate, stipes to 0.5 cm. long; style narrowly clavate, to 1.5 cm. long; torus very oblique, hypogynous gland prominent, entire, horseshoe-shaped or nearly annular. Fruit yellow, compressed, oblique, 3–4 cm. long, 2.5–3 cm. wide, and 2.5 cm. deep; endocarp bony, roughened; seed edible.

A very widely spread species from the Caroline Islands in the north through New Guinea and the Solomon Islands to the New Hebrides in the south. To the specimens cited by the authors quoted above the following can be added:

Northeast New Guinea: Heath Island, Open Bay (nr. New Britain), in rain forest on vol-

canic soil, K. Mair, N.G.F. 1878 (flowers) May, 1945 (tree 60 ft., stilt-rooted to 2 ft. 6 in.; bark light brown with pustules in longitudinal lines; flowers yellow-green). Solomon Islands: New Georgia Group, Kolombangara Island, in lowland rain forest, F. S. Walker & C. T. White B.S.I.P. 183 (leaves and seeds from under the tree) October, 1945 (tree 70 ft., buttresses supporting the trunk off the ground on stilt roots 6 ft. high; bark grey-brown, roughened with numerous fine pustular lenticels; seeds with an edible, pleasantly flavoured kernel).

It is with some hesitation that I have united all the species quoted above with *F. chloroxantha* Diels, especially as Sleumer (*loc. cit.*), who had the opportunity of seeing the type of this species, kept it distinct from the others. Knowing, however, the extreme variability of many of the Proteaceae, especially when they are brought into cultivation, I have after considerable thought decided to regard *F. chloroxantha* Diels as a "formenkreis" species with several geographical races. It seems to differ from subsequently named species only in the larger leaves and longer inflorescences.

Sleumer (*loc. cit.*) suggested that *Grevillea elaeocarpifolia* Guillaum. was identical with *Grevillea densiflora* C. T. White but did not actually synonymise the two species. Kajewski when in Bougainville, according to his field labels, recognized the tree there as practically identical with the one in the New Hebrides. In this latter area he mentions that the trees are frequently seen about villages and appear to be planted as the seed is quite an important food nut. The New Hebrides tree which was aptly named by Guillaumin (1932) as *Grevillea elaeocarpifolia*, judging from Kajewski's material (two numbers), seems to have consistently smaller leaves, but this is an extraordinarily variable feature in the New Guinea tree of which I have seen a good range of specimens.

*Finschia micronesica* Kanehira, according to the author's description and illustrations, seems to differ in the inflorescence being much shorter





FIG. 3. *Finschia chloroxantha* Diels (*Grevillea elaeocarpifolia* Guillaumin). New Hebrides: S. F. Kajewski 350.

with fewer, less crowded flowers and in the fruits being slightly larger than in the New Guinea, Solomon Islands, and New Hebrides trees, but it is doubtful if these are points of specific value.

#### ACKNOWLEDGMENTS

I am indebted to the authorities of the Arnold Arboretum (Harvard University) for photostat copies of Kanehira's papers, which were unavailable to me in Brisbane, and to Mr. E. H. Flint of the Queensland University for a translation of Kanehira's original description (in Japanese) in *Flora Micronesica*.

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# The Alcyonaria of Bikini and Other Atolls in the Marshall Group. Part I: The Gorgonacea<sup>1</sup>

FREDERICK M. BAYER<sup>2</sup>

THIS REPORT COVERS the alcyonarian corals collected during two expeditions to the Marshall Islands conducted by the United States Navy and other agencies. The Gorgonacea are considered in the present part, and the lesser groups (Stolonifera and Alcyonacea) will be taken up in Part II.

I wish to acknowledge my indebtedness to the Project Officer of the Bikini Scientific Resurvey Expedition (1947), Captain Christian L. Engleman, U. S. N.; to Dr. John W. Wells, United States Geological Survey, with whom I worked often in the field; to Dr. L. P. Schultz and Dr. J. P. E. Morrison, my colleagues of the U. S. National Museum, who extended every assistance possible; and last, but certainly not least, to Fred C. Zimmerman, Seaman 2/c, of the *Chilton's* crew, whose services were assigned me during a part of the expedition.

## THE ALCYONARIA

The Alcyonaria inhabiting the coral reefs of the Pacific Ocean are a much less conspicuous element of the fauna than those of the tropical Atlantic. The reef-dwelling forms of the Pacific are the inconspicuous Alcyonacea and the stoloniferan, *Tubipora musica*. The only alcyonarian of real importance to reef formation is the blue coral, *Heliopora*. The holaxonian Gorgonacea occur only in the deeper waters of the lagoons and surrounding ocean and must be taken by dredge.

During "Operation Crossroads," the first expedition to the Marshalls, collecting was con-

centrated upon the reefs, and therefore few Alcyonaria, none of which were Gorgonacea, were obtained. However, on the second trip the LCI 615 was fitted for deep-water dredging, and under the direction of Dr. R. Dana Russell many hauls, which accounted for all but one of the gorgonacean species collected during the entire operation, were made in the waters surrounding Bikini Atoll. The alcyonaceans taken in the dredge, along with the littoral forms collected on the reefs of Bikini and Rongerik by the author and Fred Zimmerman, will be discussed in Part II of this report.

The classification of the Alcyonaria is not, in certain respects, entirely satisfactory. A case in point is the questionable scope of the family Muriceidae, whose species constitute the major portion of this paper. However, since the present report is in no sense revisionary, this aspect of the problem must await treatment in more comprehensive studies.

Since the literature concerning these animals has in the past been typified by inadequate and imperfect illustration of the species, it has been of primary concern to figure adequately, both microscopically and macroscopically, all the species herein discussed.

Gorgonacea were taken at four stations:

STATION 9. Off Bikini Atoll, 11° 29' 16" N., 165° 20' 45" E.; depth 50-96 fathoms. August 6, 1947.

STATION 12. Off the seaward shore of Bikini Island, Bikini Atoll, 11° 28' 23" (?) N., 165° 31' 35" (?) E.; depth 58-90 fathoms. August 7, 1947.

STATION 23. Bikini Lagoon, east end, Bikini Atoll, 11° 31' 51" N., 165° 32' 53" E.; depth 5-12 fathoms. August 15, 1947.

STATION 30. Off Enyu Pass, Bikini Atoll, 11° 29' 28" N., 165° 31' 40" E.; depth 116-120 fathoms. August 22, 1947.

<sup>1</sup> Published with the permission of the Secretary of the Smithsonian Institution. Manuscript received November 17, 1948.

<sup>2</sup> Assistant Curator, Division of Marine Invertebrates, U. S. National Museum.

A list of the species collected by the Bikini Scientific Resurvey is given here:

Order GORGONACEA  
Sub-order SCLERAXONIA

*SUBEROGORGIIDAE*

1. *Suberogorgia mollis* (Nutting)

Sub-order HOLAXONIA  
*KEROEIDIDAE*

2. *Keroeides koreni* Wright and Studer

*MURICEIDAE*

3. *Paracis squamata* (Nutting)

4. *Paracis orientalis* (Ridley)

5. *Muricella englemani* new species

6. *Echinogorgia russelli* new species

7. *Villogorgia zimmermani* new species

8. *Villogorgia zimmermani* form *pallida* new

9. *Villogorgia compressa* Hiles

*PRIMNOIDAE*

10. *Caligorgia pseudoflabellum* new species

*GORGONELLIDAE*

11. *Scirpearia erythraea* Kükenthal

12. *Toeplitzella laevis* (Verrill)

Genus SUBEROGORGIA Gray

*Suberogorgia mollis* (Nutting)

Figs. 1f, 2 g-b; Pl. 4, fig. 1

*Euplexaura mollis* Nutting 1910b: 13, pl. 3, figs. 4, 4a; pl. 4, fig. 8.

*Euplexaura mollis* Kükenthal 1919: 224.

*Euplexaura mollis* Kükenthal 1924: 94.

*Suberogorgia mollis* Stiasny 1937: 98, text fig. FF; pl. 8, fig. 47.

*Suberogorgia mollis* Stiasny 1940a: 203.

*Diagnosis:* Colony erect, flabellate, branched in one plane; branching with frequent anastomosis forming a network with elongate rectangular meshes. Largest branches and the end twigs round in cross section, the intermediate ones flattened at right angles to the plane of branching. Twigs 1.5 to 2.0 mm. in diameter, flat branches about 7.0 by 10.0 mm. in diameter, large main branches 30 mm. and probably more. Anthocodiae retractile into very low ver-

rucae scarcely separable from surrounding coenenchyma; aperture with eight distinct lobes. Verrucae on all sides of the branches, mostly 0.75 to 1.0 mm. apart. Anthocodial armature of eight points of spindles in converging rows and collaret of short spindles transversely arranged. Axis composed of smooth, irregularly branched spicules and horny substance. Color, in life, bright orange; in dry condition, dirty brown. Sclerites of deep layers of coenenchyma blunt spindles with prominent belts of warts; in superficial layers double clubs or double wheels with smooth, sharply constricted shaft; those at surface with heads unilaterally produced into a pair of granular lobes.

*Spicule measurements:*

Spindles:  $0.1 \times 0.04$  mm.;  $0.08 \times 0.045$  mm.

Symmetrical double clubs:  $0.05 \times 0.034$  mm.;  $0.026 \times 0.02$  mm.

Asymmetrical double clubs:  $0.03 \times 0.03$  mm.;  $0.045 \times 0.035$  mm.

*Locality:* Enyu Island, Bikini Atoll, on edge of a large coral knoll in about 45 feet of water, August, 1947.

*Specimen:* Dry fragments, U.S.N.M. No. 44074.

*Remarks:* This specimen, of which the U. S. National Museum possesses only fragments, was about 8 feet high when complete, and so large that only one of the branches could be collected. Dr. Robert W. Hiatt, of the University of Hawaii, found it while diving on a submerged reef off Enyu Island. When alive the colony was a bright orange color, according to Dr. Hiatt, but after a few hours in the air it assumed the brownish hue which it still retains. The greater part of the specimen is in the collection of the University of Hawaii.

Stiasny first recognized that Nutting had erred in calling this scleraxonian a plexaurid. However, the calcareous deposits of the axis take a definite spicule form, unlike those of the Plexauridae. In its cortical spiculation it is similar to *S. verriculata*, although the asymmetrical double wheels of the surface layers are not identical with those figured by Aurivillius



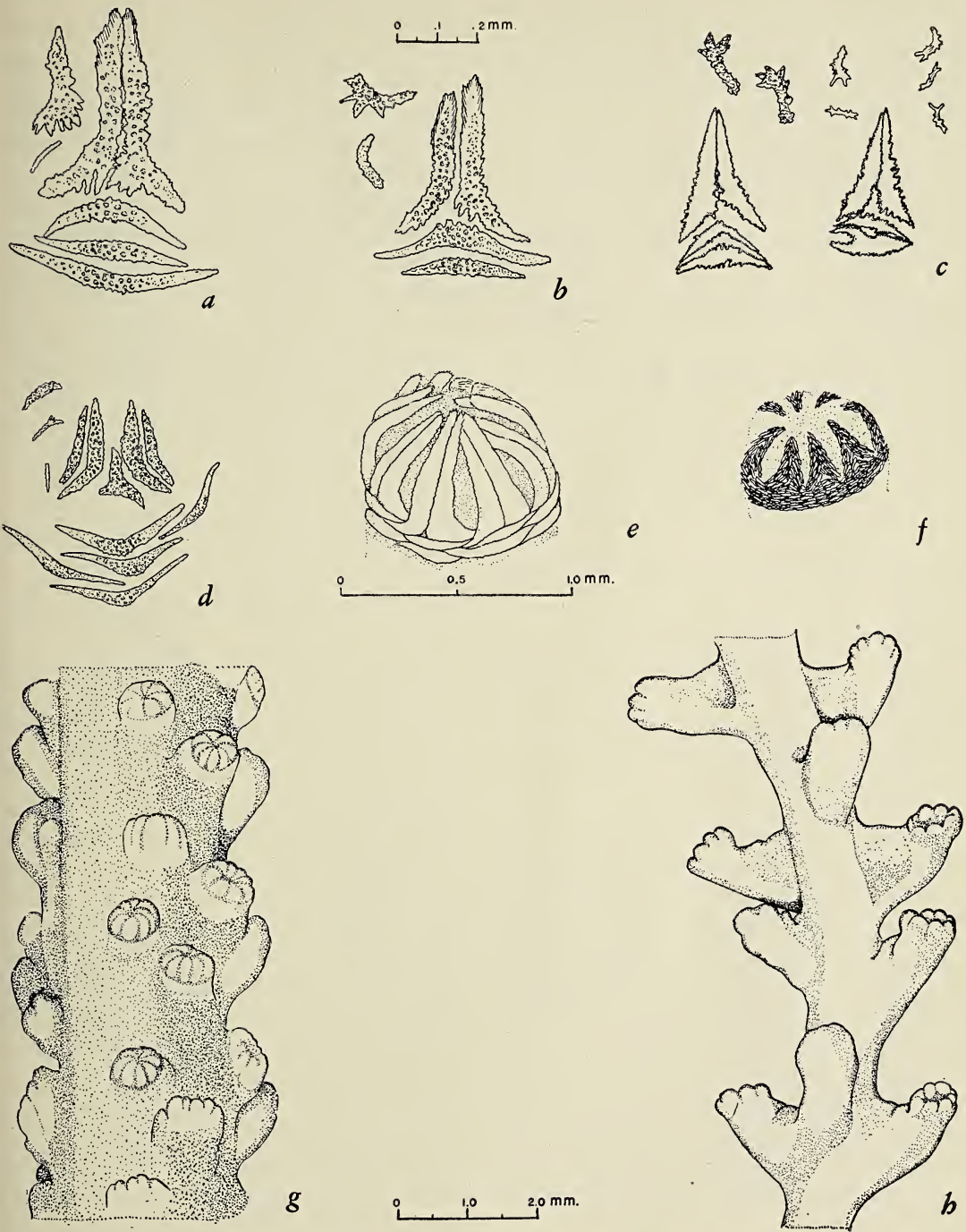


FIG. 1. *a*, *Villogorgia zimmermani*: Spicules of the opercular point, collaret, tentacles, and pinnules. *b*, *Villogorgia zimmermani* form *pallida*: Spicules of the opercular point, collaret, tentacles, and pinnules. *c*, *Villogorgia compressa*: Spicules of the opercular point, collaret, tentacles, and pinnules. *d*, *Echinogorgia russelli*: Spicules of the opercular point, collaret, tentacles, and pinnules. *e*, *Paracis orientalis*: Oblique view of retracted zooid with its armature. *f*, *Suberogorgia mollis*: Oblique view of retracted zooid with its armature. *g*, *Toeplitzella laevis*: Part of branch, enlarged, showing arrangement of verrucae. *h*, *Scirpearia erythraea*: Part of the stem, enlarged, showing arrangement of verrucae.

(1931: 20). The manner of branching and anastomosis is quite different, the meshes of *S. mollis* being much longer and more regular than those of *S. verriculata*.

Genus *KEROEIDES* Wright and Studer

*Keroeides koreni* Wright and Studer

Pl. 3, fig. 3

*Keroeides koreni* Wright and Studer 1889: 169, pl. 40, fig. 3.

*Keroeides gracilis* Whitelegge 1897: 308, pl. 16, figs. 1-5.

*Keroeides gracilis* + *K. pallida* Hiles 1899: 201, pl. 22, figs. 12-16.

*Keroeides gracilis* Thomson and Henderson 1905: 287.

*Keroeides gracilis* + *K. koreni* Thomson and Henderson 1906: 22, pl. 1, figs. 6-7; pl. 4, figs. 1-3.

*Keroeides koreni* Thomson and Simpson 1909: 167.

*Keroeides koreni* Kinoshita 1910: 226.

*Koroieides* [*sic*] *koreni* Nutting 1911: 31, pl. 6, figs. 3, 3a.

*Keroeides koreni* Kükenthal 1919: 120.

*Keroeides koreni* Kükenthal 1924: 46.

*Keroeides koreni* Aurivillius 1931: 38.

**Diagnosis:** Colony erect, branched in one plane, with occasional anastomosis. Stems round in cross section, 2.5 mm. in diameter; twigs also round, 1.0 mm. in diameter. Sub-conical verrucae 1.0 mm. in width at the base by 1.0 mm. in height, and from 1.5 to 4.0 mm. apart, biserially and often alternately along the sides of the branches. Coenenchyma thin, filled with large fusiform to oval, and sometimes flattened, spicules; zooids armed with smaller spindles. Sclerites bright red in color. Axis composed of smooth, terete spindles, light red in color, joined together by horny matter. Entire colony bright red, axis paler.

**Spicule measurements:**

Spindles:  $1.05 \times 0.25$  mm.;  $0.47 \times 0.14$  mm.;  $0.39 \times 0.11$  mm.

Ovals:  $0.54 \times 0.21$  mm.

Spindles of the zooids:  $0.15 \times 0.03$  mm.

Spindles of the axis:  $0.32 \times 0.06$  mm.;  $0.25 \times 0.04$  mm.

**Locality:** Station 12.

**Specimen:** One, preserved dry, U.S.N.M. No. 44075; branches thereof in alcohol, U.S.N.M. No. 44076.

**Remarks:** The Resurvey obtained one fine specimen, 127 mm. in height and 105 mm. in maximum width, which agrees very closely with the original and subsequent descriptions.

Genus *PARACIS* Kükenthal

*Paracis squamata* (Nutting)

Fig. 6a-e; Pl. 1, fig. 1

*Acis squamata* Nutting 1910a: 42, pl. 7, figs. 2, 2a; pl. 20, fig. 50.

*Acis squamata* Nutting 1912: 81.

*Paracis squamata* Kükenthal 1924: 158.

*Acis squamata* Thomson and Dean 1931: 200, pl. 5, fig. 2; pl. 16, fig. 9.

*Paracis squamata* Aurivillius 1931: 145 (in key only).

**Diagnosis:** "Colony flabellate, 14.3 cm. in height and with a spread of 4.9 cm. The main stem is round, 3.8 mm. in diameter. 1.6 cm. from its base it gives off a short branch, and from that point to near its distal end it gives off roughly alternate branches, several of which give off branchlets nearly all of which are on one side of the branch. The branches near the distal end of the colony are more symmetrical in their branchings than the more proximal ones. The calyces are borne almost exclusively on the sides and front of the stem and branches, where they are unevenly distributed, varying from .5 mm. to 2.2 mm. in the distance between them.

"The individual calyces are short tubes averaging about 1.5 mm. in height, and about the same in diameter. Their walls are composed of plate-like or scale-like spicules of various shapes; but fitted to each other, although they sometimes overlap somewhat. The ends, or edges, of the distal row form a scalloped border around the calyx margin. There seems to be no regularity whatever in the disposition of these calyx spicules. They are also exceedingly irregular in



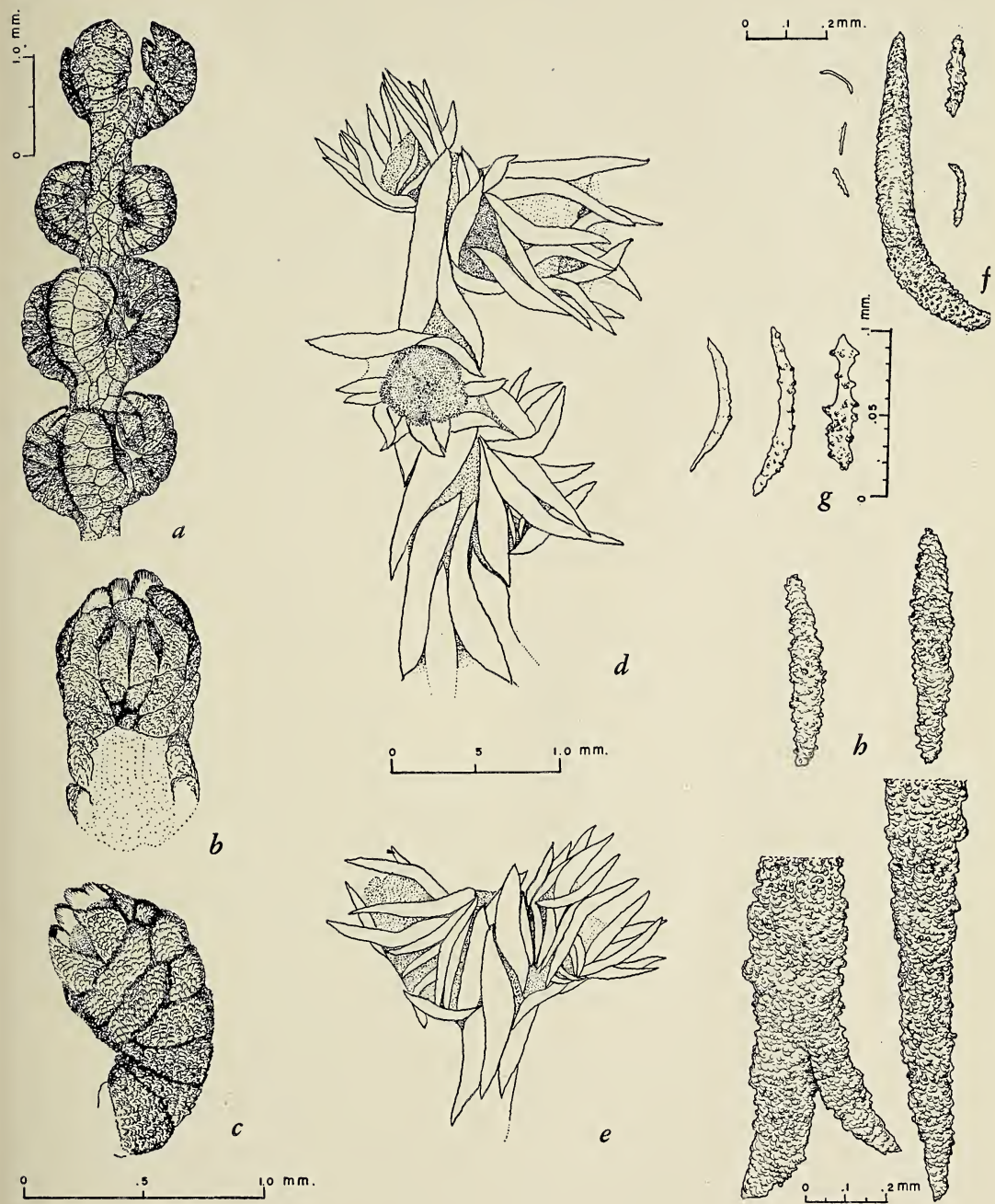


FIG. 2. *a-c*, *Caligorgia pseudoflabellum*: *a*, part of twig, enlarged, showing arrangement of the whorls of zooids; *b*, adaxial view of zooid; *c*, lateral view of zooid. *d-h*, *Muricella englemani*: *d*, *e*, parts of twigs, enlarged, showing calyces; *f*, spicules of calyx and tentacles; *g*, spicules of tentacles; *h*, spicules of the coenenchyma.

shape, being squarish oblong with rounded corners, rudely triangular, or irregular polygons of various sorts. The ones on the basal part of the calyx are usually larger than those on the distal part. The polyps are retractile, but it is doubtful if the calyx walls can completely cover the operculum. The latter is composed of relatively heavy spindles or bar-like forms. Two of these are often closely fitted together and curved over a tentacle to form a solid opercular segment or flap.

"Spicules. Some of the largest spicules of the Gorgonacea are found in this species. Those covering the coenenchyma are closely and exactly fitted together along all their contiguous edges. They are squarish or oblong plates of various forms, and attain a length of 5 mm. and a diameter of 2 mm. Typical spindles are rarely seen. The edges of the spicules are often regularly but minutely ctenate, and their surface is covered with fine granules.

"Color. The entire colony is ivory white in alcohol. The axis is light yellowish gray, and the spicules are colorless." (Nutting, 1910a.)

To Professor Nutting's description I add: Colony erect, flabellate, branched in one plane. Without anastomosis. Stem and branches round, stems 2.5 mm. in diameter, twigs near their ends about 2.0 mm. Anthocodiae retractile into tubular verrucae which are unevenly distributed over three sides of the stems and branches, i.e., "back" face of the flabellum practically free of zooids. Verrucae 1.5 mm. high and 1.5 mm. wide at base, separated by intervals of from 1.0 to 3.0 mm. Verrucal walls irregularly covered with closely fitted scale-like plates. Anthocodial armature of eight points each composed of two spindles bent sharply outward at proximal end; these spicules quite variable, members of a pair may differ considerably in size. Tentacles armed with small spindles and curved forms furnished with prominent conical processes. Spicules of the coenenchyma oblong or squarish thick plates, closely fitted together. Anthocodial spicules colorless, plates of cortex white.

*Spicule measurements:*

Plates of the coenenchyma:  $2.85 \times 1.25$  mm.;  $0.7 \times 0.65$  mm.; up to  $5.0 \times 2.0$  mm.

Calyx marginals:  $0.6 \times 0.35$  mm.;  $0.69 \times 0.49$  mm.

Opercular:  $0.61 \times 0.07$  mm.;  $0.64 \times 0.08$  mm.

Tentacular:  $0.15 \times 0.025$  mm.;  $0.15 \times 0.035$  mm.;  $0.18 \times 0.03$  mm.

*Locality:* Station 30.

*Specimen:* U.S.N.M. No. 44077, preserved in alcohol.

*Remarks:* The Resurvey Collection contains a fine specimen of this unmistakable muriceid. It consists of two large flabellate portions arising from an expanded base free of zooids, from which some smaller stems also arise. The secondary branches arise at slightly less than  $90^\circ$  angles, and soon bend upward. Branching is usually, but not always, alternate, chiefly in one plane; the branches do not anastomose. The species has been taken previously only by the "Siboga" and "Albatross."

*Paracis orientalis* (Ridley)

Figs. 1e, 5a-e; Pl. 1, fig. 4

*Acis orientalis* Ridley 1882: 126, pl. 5, figs. 1-6.

*Diagnosis:* Colony erect, irregularly branched in one plane, without anastomosis; flabellum arising from a distinctly expanded and encrusting base which bears numerous zooids. Stems round in cross section, 2.5 mm. in diameter; twigs, near end, 1.5 to 1.75 mm. in diameter. Anthocodiae retractile into low, tubular to dome-like verrucae, distributed on all sides of the colony, less common on the "back" face. Verrucae vary considerably in size, most commonly 1.0 mm. in diameter by 0.5 mm. or less in height, sometimes 2.0 mm. in basal diameter by over 0.5 mm. in height. Verrucal walls covered with irregular, multispinose scales, latter, at distal margin, reduced to simple spine with flattened, tubercular base. Anthocodial armature consisting of eight points, each formed of two contiguous bent spindles, and two curved spindles placed transversely beneath each point, to-



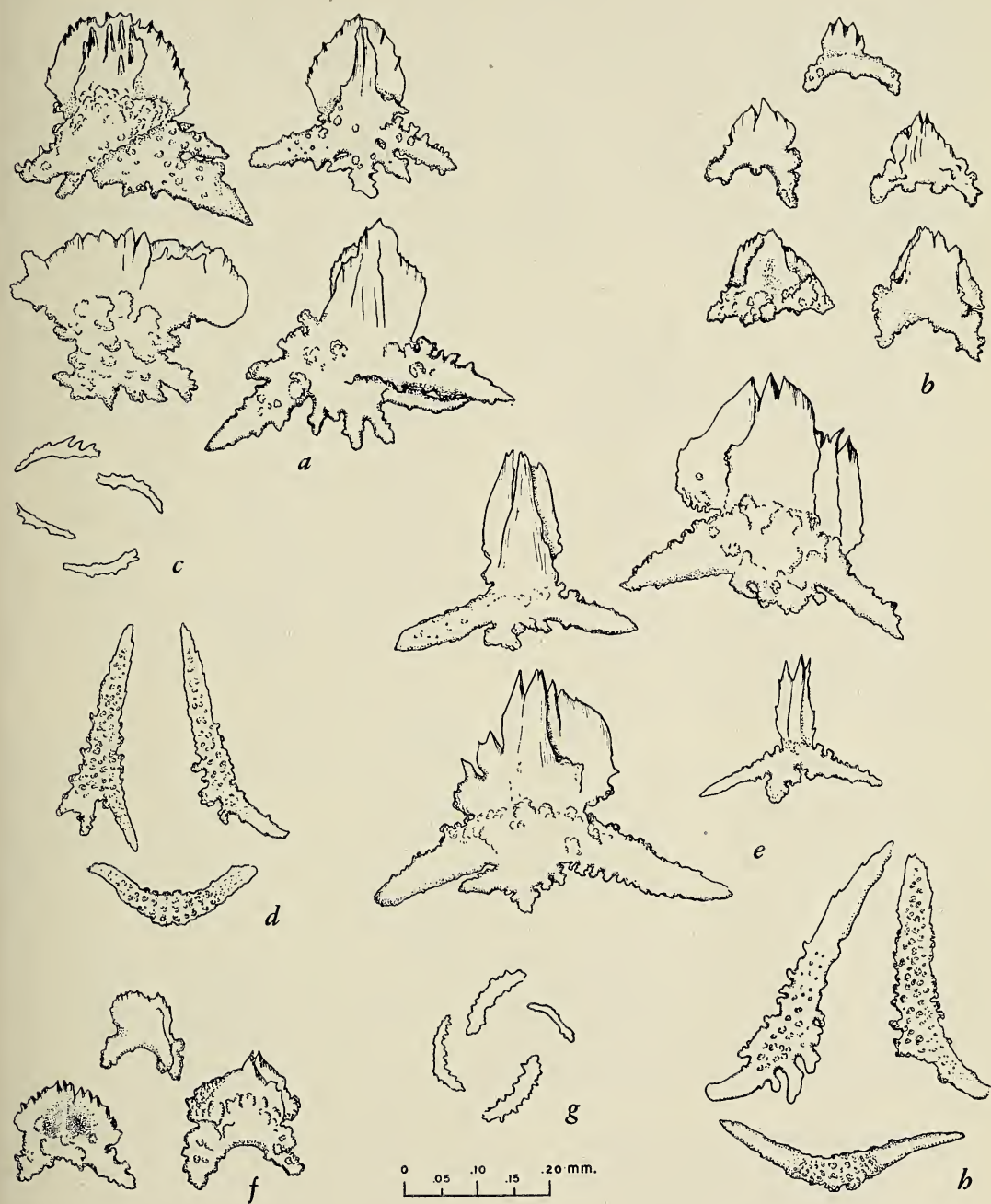


FIG. 3. *a-d*, *Villogorgia zimmermani* form *pallida*: *a*, spicules of the calyces; *b*, of the coenenchyma; *c*, of the tentacles; *d*, operculum and collar. *e-h*, *Villogorgia zimmermani*: *e*, spicules of the calyces; *f*, of the coenenchyma; *g*, of the tentacles; *h*, operculum and collar.

gether forming collaret ring. Tentacles further provided with curved, spinose, club-like spicules, and pinnulae with smaller straight spindles. Coenenchyma covered with irregular elongate plates very closely fitted as in mosaic. These ornamented with low protuberances, quite spinose near the calyces. Axis horny, flexible, yellowish-brown in color. Spicules of anthocodiae colorless, those of stems grayish white. Colony as a whole brownish-gray in color, with verrucae darker.

*Spicule measurements:*

Coenenchyma:  $0.32 \times 0.11$  mm.;  $0.39 \times 0.15$  mm.;  $0.38 \times 0.15$  mm.;  $0.41 \times 0.14$  mm.;  $0.94 \times 0.42$  mm.;  $1.5 \times 0.5$  mm.

Calyx marginals:  $0.67 \times 0.24$  mm.;  $0.66 \times 0.24$  mm.;  $0.45 \times 0.10$  mm.

Opercular:  $0.665 \times 0.1$  mm.;  $0.565 \times 0.08$  mm.;  $0.3 \times 0.065$  mm.

Tentacular:  $0.36 \times 0.06$  mm.;  $0.36 \times 0.065$  mm.;  $0.36 \times 0.05$  mm.

Collaret:  $0.6 \times 0.1$  mm.;  $0.5 \times 0.05$  mm.;  $0.42 \times 0.035$  mm.;  $0.415 \times 0.06$  mm.

*Locality:* Station 30.

*Specimens:* U.S.N.M. No. 44078, preserved in alcohol.

*Remarks:* The Resurvey Collection contains a moderately large example of this species (85 mm. in height and 77 mm. in width) consisting of two stems which arise from the spreading, encrusting base covering a branch of coral. The lateral branches arise at intervals of 10 to 15 mm. along the main stem, occasionally more or less. There is also a small colony 35 mm. in height which differs in no essential detail. It may be observed that this species will not key out satisfactorily in Kükenthal's key to the genus *Paracis*.

Genus MURICELLA A. E. Verrill  
*Muricella englemani* new species

Fig. 2*d*-*b*; Pl. 2, fig. 1

*Diagnosis:* Colony erect, spreading, flabellate, branched in one plane. Anastomosis frequent and irregular. Branches sinuous, knotty in places, with tendency to flatten at almost any angle to the plane of branching, varying with position in

the colony. Main stem, before dividing, and smallest twigs, round in cross section. Twigs tend toward an opposite arrangement on branches. Larger branches  $1.5 \times 3.0$  mm. in diameter, twigs 1.0 mm. Zooids small, on all sides of the colony, in short tubular verrucae, latter 1.0 mm. high by 0.7 mm. wide. Verrucal margin formed of eight points of one or more pairs of bent spindles which do not close over the tentacles in retraction. Tentacles with small, often curved, sparsely warted spindles. Coenenchyma thin, covered with layer of large, often twisted spindles, irregularly and densely warted on all sides; deeper layer of generally smaller spindles between them. Axis completely horny, dark brown or black in color, visible through crust-like layer of cortical spicules.

*Spicule measurements:*

Spindles from verrucal points:  $0.58 \times 0.06$  mm.;  $0.87 \times 0.10$  mm.

Spindles from tentacles:  $0.16 \times 0.02$  mm.;  $0.21 \times 0.05$  mm.;  $0.08 \times 0.02$  mm.

Spindles from coenenchyma:  $0.60 \times 0.11$  mm.;  $0.49 \times 0.09$  mm.;  $2.07 \times 0.27$  mm.

*Locality:* Station 9.

*Specimen:* The holotype, dry, U.S.N.M. No. 44079; branches of same, in alcohol, U.S.N.M. No. 44080.

*Remarks:* The type is a large, nearly perfect colony 260 mm. in height by 400 mm. in width. It is attached by a trunk 5 mm. in diameter to a piece of coral rock. The base is not expanded.

Genus ECHINOGORGIA Kölliker  
*Echinogorgia russelli* new species

Figs. 1*d*, 4*c*; Pl. 3, fig. 4

*Diagnosis:* Colony erect, flabellate, branched in one plane. Branching alternate to irregular, with frequent anastomosis, forming open network. End twigs 1.25 to 1.5 mm. in diameter, bent upward, somewhat thickened at tips. Larger branches 2.0 to 2.5 mm. in diameter, flattened at right angles to plane of branching. Anthocodiae retractile into low, dome-like verrucae, 1 mm. in diameter by 0.5 mm. or less in height, closely placed on all sides of branches and twigs,





FIG. 4. *a, b, Villogorgia compressa*: *a*, spicules of the calyces; *b*, of the coenenchyma. *c, Echinogorgia russelli*: Spicules of the calyces. *d, Scirpearia erythraea*: Spicules. *e, Toeplitzella laevis*: Spicules. *f, Caligorgia pseudoflabellum*: *f*<sub>1</sub>, spicules of the operculum; *f*<sub>2</sub>, of the marginal row; *f*<sub>3</sub>, the coenenchyma. *g, b, Suberogorgia mollis*: *g*, spicules of the coenenchyma, the double clubs from the surface, and the warted spindles from the deeper layer; *b*, spicules of the axis. (Upper scale applies to *a, b, c, f, b*; lower to *d, e*.)

commonly in spiral arrangement. Anthocodial armature eight points, formed by two or more pairs of bent spindles arranged *en chevron*, with one or two smaller spicules filling basal interspace; prominent collaret of four or five rows of strongly curved, transversely arranged spindles below points. Coenenchyma and verrucae filled with multiradiate forms and "Stachelkeulen" of the type shown by Hickson (1932: 481, text fig. 6a, b). Leaves of these spicules project from surface of coenenchyma and verrucal walls rendering these surfaces prickly and verrucal orifice serrate. Axis dark brown, horny, without calcareous deposits. Color of colony light brick-red, sclerites light reddish or orange; opercular spindles colorless.

*Spicule measurements:*

"Stachelkeulen":  $0.21 \times 0.19$  mm.;  $0.3 \times 0.15$  mm.;  $0.2 \times 0.175$  mm.

Radiate forms:  $0.24 \times 0.15$  mm.;  $0.21 \times 0.16$  mm.

Spindle of opercular point:  $0.25 \times 0.05$  mm.

Spindle of collaret:  $0.31 \times 0.02$  mm.

*Locality:* Stations 9, 23.

*Specimens:* The holotype, dry, U.S.N.M. No. 44082; portions in alcohol U.S.N.M., No. 44083; paratypes, dry, U.S.N.M. No. 44081.

*Remarks:* The Resurvey Collection contains three specimens which measure as follows:

The holotype: 190 mm. high, 114 mm. wide (Sta. 23).

The paratypes: 190 mm. high, 207 mm. wide (Sta. 9); 86 mm. high, 36 mm. wide (Sta. 9).

This species appears to have been undescribed heretofore, and I take pleasure in dedicating it to Dr. R. Dana Russell, through whose efforts the specimens were obtained.

Genus VILLOGORGIA Duchassaing and Michelotti

*Villogorgia zimmermani* new species

Figs. 1a, 3e-h; Pl. 3, fig. 1

*Diagnosis:* Colony erect, flabellate, branched in one plane; without anastomosis. Branching alternate, opposite, and sometimes unilateral for considerable distances. Stems round, 3.0 mm. in

diameter; branches 1.5 mm.; twigs, near the ends, 1.0 mm. Anthocodiae retractile into short, tubular verrucae, points of the operculum usually not entirely withdrawn into it. Verrucae, from 1.0 to 1.5 mm. in width by slightly less in height, scattered irregularly over three sides of stems and branches, less abundantly on fourth. Calyces usually about 2.0 to 2.5 mm. apart, closest toward tips of twigs; two on twig ends usually opposed. Anthocodial armature of eight points, each formed by two longitudinally arranged contiguous spindles bent outward at proximal end; a collaret ring composed of two curved spindles transversely placed beneath each point. Verrucae thickly beset with "*Acamptogorgia*-type" (Nutting, 1910a) spicules, whose foliate and spinose ends project from surface and impart a rugose appearance. Coenenchyma filled with smaller forms with projecting foliaceous part, and two to four root-like, thickly warted processes. All sclerites rose-purple, those of operculum much paler. Axis horny, with no calcareous deposits. Color of colony deep wine-purple, with spaces between spicule folia darker; zooids brownish; axis light brown.

*Spicule measurements:*

Opercular spindles:  $0.35 \times 0.09$  mm.;  $0.33 \times 0.06$  mm.

Collaret spindles:  $0.27 \times 0.055$  mm.;  $0.25 \times 0.04$  mm.

Foliate spicules of the verrucae and coenenchyma:

Width across roots	Diameter of roots at base	Height of folia	Width of folia
VERRUCAE			
0.32	0.06	0.145	0.09
0.45	0.08	0.12	0.17
0.41	0.05	0.15	0.15
0.30	0.06	0.145	0.19
0.39	0.05	0.215	0.10
0.63	0.12	0.23	0.13
0.45	0.10	0.29	0.16
COENENCHYMA			
0.18	0.04	0.10	0.16
0.19	0.06	0.11	0.175
0.13	0.35	0.06	0.09





FIG. 5. *a-e*, *Paracis orientalis*: *a*, spicules of the calicular margin; *b*, of the verrucal wall; *c*, of the verrucal base and adjacent cortex; *d*, of the anthocodial armature, including one of the points (1), clubs from the tentacles (2 and 3), curved spindles of the collaret (4), and spindles of the pinnules (5); *e*, part of a twig enlarged to show the arrangement of verrucae.

*Locality:* Station 30.

*Specimens:* The holotype, U.S.N.M. No. 44084, and 11 paratypes, U.S.N.M. No. 44085, preserved in alcohol.

*Remarks:* The specimens represented in the Resurvey Collection measure as follows:

Holotype:  $145 \times 120$  mm.

Paratypes:  $150 \times 120$  mm.

$125 \times 90$  mm.

$75 \times 115$  mm.

$45 \times 22$  mm.

$12 \times 18$  mm.

$21 \times 8$  mm.

$80 \times 57$  mm.

$47 \times 45$  mm.

$70 \times 45$  mm.

$50 \times 42$  mm.

$40 \times 25$  mm.

In the measurements given above, the height is listed first. The third, fourth, fifth, and sixth paratypes are all attached to the same fragment of coral, and show the variation in shape of colonies at different ages. In a fully adult colony, the stem measurements are as follows: Stem, diameter 3.0 mm.; branch, 1.5 mm.; twig, 1.0 mm. In small specimens, all the branches are about 1.0 mm. in diameter.

The sclerites of this species, when carefully cleaned and examined under a dissecting microscope, are among the most beautiful of all alcyonarian spicules. The accompanying illustrations leave much to be desired in conveying their crystalline appearance.

It is with pleasure that I name this new species for Fred Zimmerman, whose sincere enthusiasm and faithful assistance were great assets on many collecting trips.

*Villogorgia zimmermani* form *pallida* new  
Figs. 1b, 3a-d; Pl. 3, fig. 2

*Diagnosis:* Similar to *V. zimmermani* s.s., except: color, pale yellowish-brown, with colorless spicules; colony less robust, stems measuring 2.5 mm. in diameter, branches 1.25, and twigs 0.75; verrucae also somewhat smaller. Spicules same size as in typical form, but completely without

rose-purple color. Operculum identical to that of typical form.

*Locality:* Station 30.

*Specimen:* The holotype, U.S.N.M. No. 44086.

*Remarks:* Although this specimen is not specifically distinct, it differs so markedly in color, and in its general slenderness, that it seems advisable to separate it from *V. zimmermani* as a form.

### *Villogorgia compressa* Hiles

Figs. 1c, 4a-b; Pl. 2, fig. 2

*Villogorgia compressa* Hiles 1899: 200, pl. 22, fig. 7.

*Villogorgia compressa* Nutting 1910a: 71.

*Brandella compressa* Kükenthal 1924: 218.

*Villogorgia compressa* Aurivillius 1931: 225.

*Diagnosis:* Colony erect, flabellate, branched in one plane, with frequent anastomosis of both large and small branches. Branching irregular. Main stem oval in cross section, 1.0 by 2.0 mm. in diameter, flattened at right angles to plane of branching. After first major division of trunk, stems strongly compressed, 0.75 by 1.75 mm. in diameter; end twigs round, 0.5 mm. in diameter. Anthocodiae retract into prominent tubular verrucae set at right angles to stems. Verrucae from 0.75 to 1.0 mm. in height, slightly less in width, irregularly scattered over colony, less abundant on "rear face." End twigs usually with opposed pair of zooids. Axis horny, light brown, becoming paler distally. Color of dry colony dirty brown. Sclerites of verrucae horizontally arranged, with a short projecting portion of one or two short, finger-like processes, and with two flattened, branched roots. Sclerites of coenenchyma quadriradiate forms of smaller size. Anthocodial armature eight pairs of flattened spicules arranged longitudinally and forming eight points; transverse rows beneath these merge with transverse verrucal spicules, hence collar without well-defined proximal boundary.

*Spicule measurements:*

Spicules of verrucae:  $0.25 \times 0.01$  mm.;  $0.24 \times 0.01$  mm.;  $0.26 \times 0.125$  mm.



Quadriradiates of coenenchyma: 0.15 × 0.09 mm.; 0.10 × 0.06 mm.; 0.158 × 0.1 mm.  
Opercular points: 0.33 × 0.06 mm.; 0.36 × 0.07 mm.; 0.30 × 0.055 mm.  
Transverse: 0.20 × 0.04 mm.; 0.20 × 0.07 mm.; 0.25 × 0.05 mm.  
Spinose clubs of tentacles: 0.16 (length) × 0.10 (across spines) mm; 0.155 × 0.09 mm.; 0.10 × 0.055 mm.  
*Locality:* Station 9.  
*Specimen:* U.S.N.M. No. 44087 (dry), 44088 (branches in alcohol).

*Remarks:* The one specimen obtained, which is 145 mm. high and 193 mm. wide, agrees well with Miss Hiles' original description and figures.

Genus CALIGORGIA J. E. Gray  
*Caligorgia pseudoflabellum* new species  
Figs. 2a-c, 4f; Pl. 4, fig. 2

*Caligorgia flabellum* Nutting 1912: 60.  
Not *Prymnoa flabellum* Ehrenberg 1834: 358.  
Not *Primnoa flabellum* K  lliker 1865: 135, pl. 17, fig. 11.

*Diagnosis:* Colony erect, alternate-pinnately branched in one plane. Zooids in whorls of 3 or 4, rarely 5, on twigs; 28-32 whorls in 4 cm. twig length. Individual zooids ± 1.25 mm. high, clavate, bent inward, covered with closely fitted spicules heavily warted on outer surfaces. Abaxial rows with eight scales; outer lateral rows reduced to two; adaxial rows two, very small. Operculum of eight scales, adaxials smallest; rather elongate, with single broadly rounded, crenulate distal projection. Coenenchyma with irregular scales. Color creamy white. Axis calcareous, finely striate longitudinally, with metallic golden luster.

*Spicule measurements:*  
Opercular scales: 0.32 × 0.23 mm.; 0.29 × 0.19 mm.  
Body scales: 0.27 × 0.20 mm.; 0.20 × 0.18 mm.  
Coenenchyma scales: 0.13 × 0.15 mm.; 0.20 × 0.15 mm.; 0.11 × 0.13 mm.; 0.17 × 0.09 mm.; 0.11 × 0.17 mm.  
*Locality:* Station 30.  
*Specimen:* The holotype, U.S.N.M. No. 44089, in alcohol.

*Remarks:* The Resurvey Collection includes an incomplete specimen which is probably a branch from a very large colony. *Caligorgia pseudoflabellum* is identical with the species taken by the "Albatross" in Japanese waters and referred erroneously to *Caligorgia flabellum* by Professor Nutting. It differs markedly from the specimens of *C. flabellum* which Kinoshita (1908: 35) described, as can be seen from the tabulated comparison on this page.

Genus SCIRPEARIA G. Cuvier  
*Scirpearia erythraea* K  kenthal  
Figs. 1b, 4d; Pl. 1, fig. 3

*Scirpearia erythraea* K  kenthal 1913: 26, figs. 21, 22; pl. 3, figs. 8-9.  
*Scirpearia erythraea* K  kenthal 1924: 370.  
*Scirpearia erythraea* Toeplitz 1929: 302.  
Not *Scirpearia erythraea* Stiasny 1940b: 158, 171, pl. 1, fig. 5.

*Diagnosis:* Colony unbranched, flagelliform, arising from a somewhat spreading base. Primary longitudinal canals two in number. Verrucae prominent, usually somewhat bent, arranged in two series, each of two approximately alternating rows of zooids; series separated by

	<i>C. flabellum</i>	"Albatross" specimens	Resurvey specimen
No. twigs per cm. branch length . . . . .	8-18	18	14-16
Angle of origin of twigs . . . . .	30°-40°	30°-40°	30°-40°
Length of twigs . . . . .	10-20 cm.	2.5-5.0 cm.	2.5-5.0 cm.
No. whorls per 4 cm. twig length . . . . .	15-20	28-32	28-32
No. polyps per whorl . . . . .	3-8	3-5	3-5
Length of polyps . . . . .	1.5-2.0 mm.	2.0 mm.	1.25 mm.

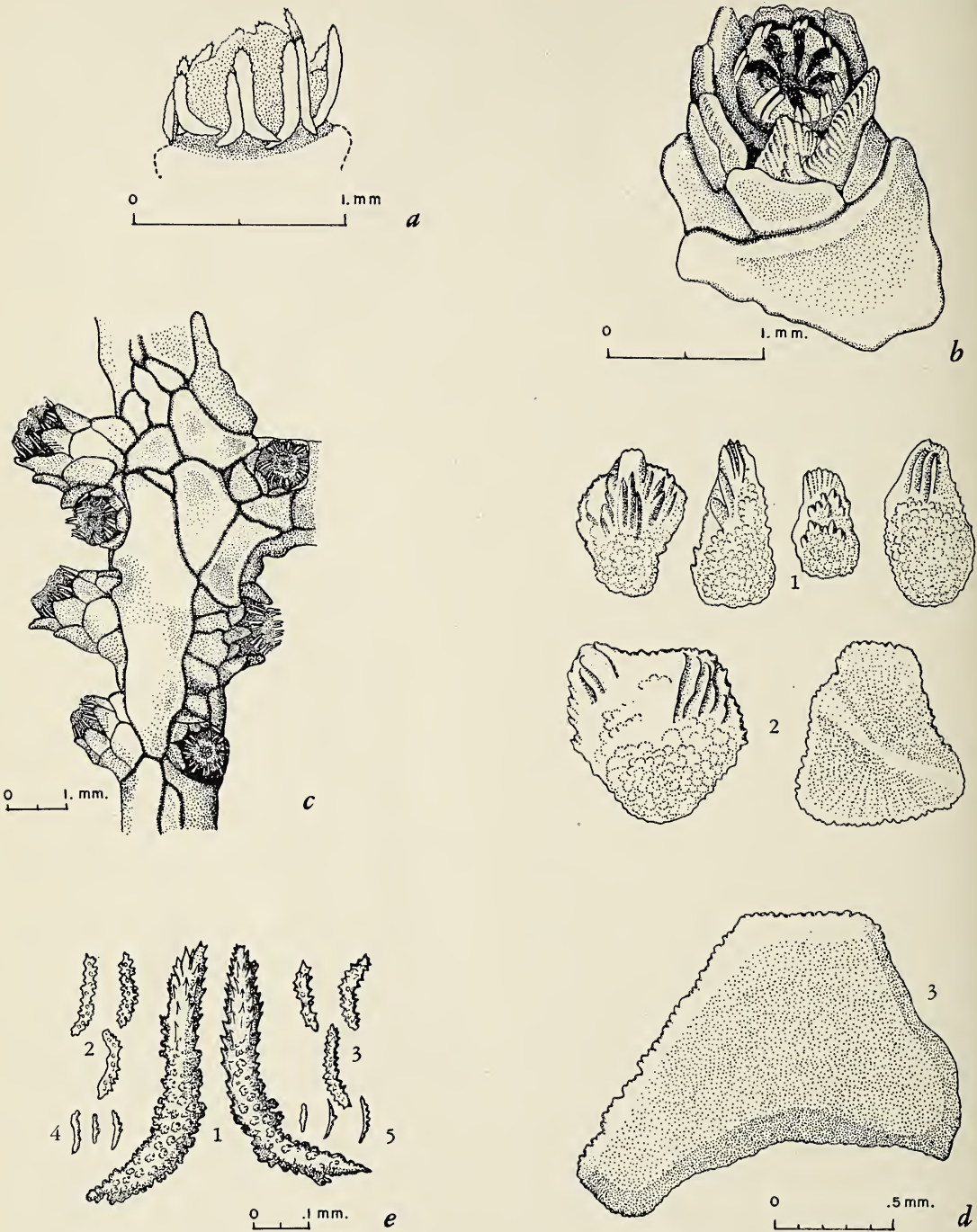


FIG. 6. *a-e*, *Paracis squamata*: *a*, side view of retracted zooid removed from calyx to show anthocodial armature; *b*, single calyx with retracted zooid; *c*, a twig enlarged to show arrangement of calyces; *d*, spicules, including spicules of the calicular margin (1), of the verrucal wall (2), and of the verrucal base (3); *e*, spicules, including one of the opercular points (1), spindles of the tentacles (2 and 3), and spindles of the pinnules (4 and 5).



barren areas corresponding to two primary canals. Verrucae absent from lower part of colony. Proximal zooids on colony very low, increasing in height distally, 2 mm. tall near middle of colony. Axis slender, calcified, with prominent concentric rings. Sclerites of verrucae mostly rather long, fairly stout, double spindles with low warts and more or less pronounced smooth girdle. Sclerites of coenenchyma symmetrical double clubs with prominent belts of warts. Color orange-ochraceous, tips of verrucae darker.

*Spicule measurements:*

Verrucae:  $0.08 \times 0.025$  mm.;  $0.075 \times 0.025$  mm.;  $0.095 \times 0.031$  mm.

Coenenchyma:  $0.06 \times 0.035$  mm.;  $0.061 \times 0.037$  mm.;  $0.062 \times 0.04$  mm.

*Locality:* Station 9.

*Specimens:* One perfect, one damaged, U.S.N.M. No. 44090.

*Remarks:* The collection contains two specimens of this gorgonellid which agree satisfactorily with Kükenthal's diagnosis and figures. The largest, broken at the tip, is 235 mm. long, with a diameter of 2.5 mm. at the base and 1.0 mm. at the upper end. The smaller, and complete, colony is 175 mm. high with a stem diameter of 1.5 mm. at the base tapering to about 0.5 mm. at the tip. Both are attached to fragments of rocks by slightly spreading bases. In the large colony, the verrucae are directed upward, especially toward the tip, as shown in Figure 1*b*, whereas in the smaller, they are bent downward. Although Kükenthal's species was described from the Red Sea, the Bikini examples agree so well with his description that there seems to be no need for separation.

Genus TOEPLITZELLA Deichmann

*Toeplitzella laevis* (Verrill)

Figs. 1*g*, 4*e*; Pl. 1, fig. 2

*Juncella laevis* A. E. Verrill 1866: 189.

*Juncella laevis* + *Scirpearia furcata* + *Scirpearia furcata* var. *robusta* + *Scirpearia robusta* (part) J. J. Simpson 1910: 306, 339, 357.

*Ellisella laevis* Stiasny 1940*b*: 170.

For detailed list of references, see Kükenthal 1924: 366.

*Diagnosis:* Colony sparsely branched. End twigs long and whip-like, 2.5 mm. in diameter near base. Anthocodiae retractile into dome-like, upturned verrucae as much as 0.5 mm. in height, arranged in two series along stems, each series of three or four alternating rows of zooids. Series separated by bare tracts corresponding to primary longitudinal canals. Coenenchyma comparatively thick, filled with double clubs whose heads have rather smooth warts. Axis gray-brown, longitudinally striate, highly calcareous, with conspicuous concentric rings. Color plain orange-red, spicules light orange.

*Spicule measurements:*

Double clubs:  $0.07 \times 0.025$  mm.;  $0.075 \times 0.048$  mm.;  $0.07 \times 0.044$  mm.

Double spindles:  $0.07 \times 0.025$  mm.;  $0.071 \times 0.026$  mm.

*Locality:* Station 9.

*Specimen:* U.S.N.M. No. 44091, in alcohol.

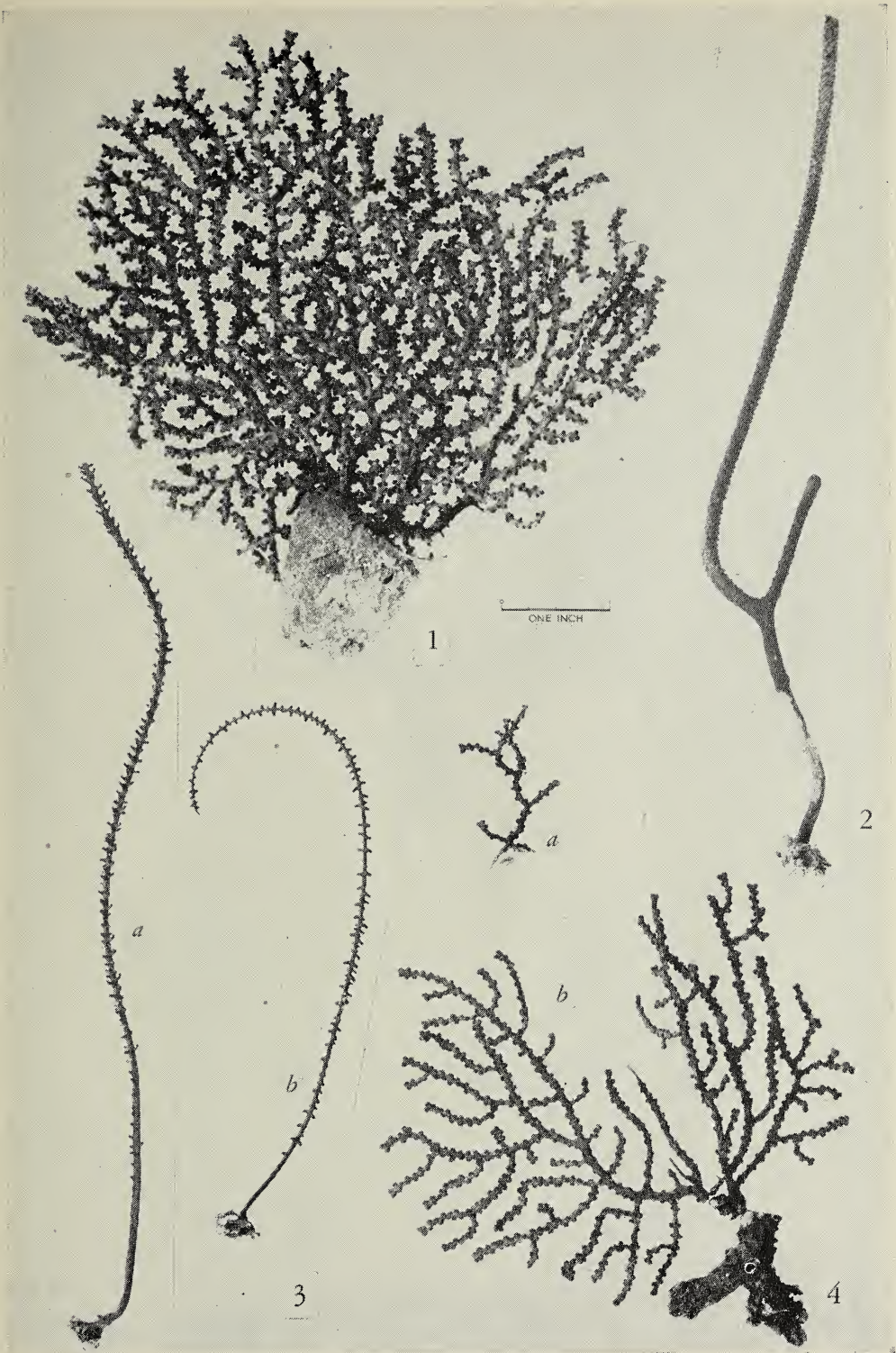
*Remarks:* The Resurvey Collection contains a damaged specimen which was probably more than 18 inches in height when complete. The colony is simply forked; zooids are absent below the fork, and most of the coenenchyma is missing on the trunk.

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ALCYONARIA PLATE 1.

FIG. 1. *Paracis squamata*.

FIG. 2. *Toeplitzella laevis*.

FIG. 3. *Scirpearia erythraea*. Two colonies.

FIG. 4. *Paracis orientalis*. Two colonies.

(OFFICIAL PHOTOGRAPHS BY THE SMITHSONIAN INSTITUTION.)





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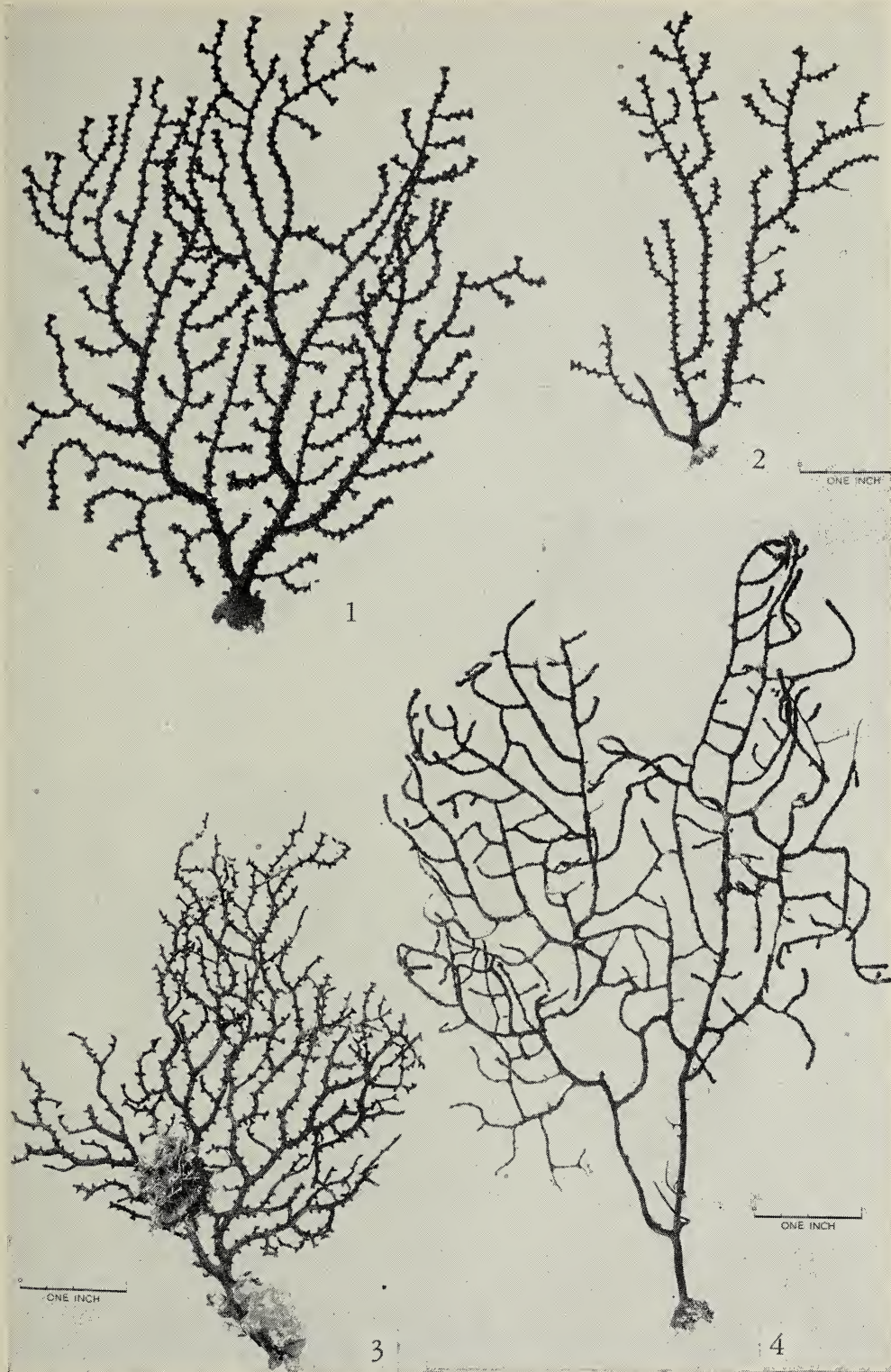
ALCYONARIA PLATE 2.

FIG. 1. *Muricella englemani*. The holotype.

FIG. 2. *Villogorgia compressa*.

(OFFICIAL PHOTOGRAPHS BY THE SMITHSONIAN INSTITUTION.)





ALCYONARIA PLATE 3.

FIG. 1. *Villogorgia zimmermani*. The holotype.

FIG. 3. *Keroeides koreni*.

FIG. 2. *Villogorgia zimmermani* form *pallida*. The holotype.

FIG. 4. *Echinogorgia russelli*. The holotype.

(OFFICIAL PHOTOGRAPHS BY THE SMITHSONIAN INSTITUTION.)





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ALCYONARIA PLATE 4.  
FIG. 1. *Suberogorgia mollis*.  
FIG. 2. *Caligorgia pseudoflabellum*. The holotype.  
(OFFICIAL PHOTOGRAPHS BY THE SMITHSONIAN INSTITUTION.)



# A Review of Concepts in Hawaiian Climatology<sup>1</sup>

LUNA B. LEOPOLD AND C. K. STIDD<sup>2</sup>

IN HAWAII, which is noted for its equable climate, the lack of great variations between seasons often obscures the importance of day-to-day and geographic variations in weather.

Hawaii owes its relatively uniform climate to its position with respect to the sub-tropical high pressure cell and accompanying ocean currents. The rugged topography causes salient orographic rainfall patterns. The variations in annual rainfall through short horizontal distances are common knowledge among residents of Hawaii. Areas in the mountains immediately behind Honolulu receive up to 160 inches annually, while at the seashore, 5.5 miles away from the mountains, less than 15 inches is recorded. On Kauai, the annual mean varies from 450 to 20 inches in a horizontal distance of 12 miles.

The changes of greatest economic importance, surprisingly enough, are those that occur between consecutive months and between consecutive years. The growing of pineapples and of sugar cane represents the two most important industries in the Hawaiian Islands. These industries, which utilize a large proportion of the arable land in the rainfall zone between 20 and 100 inches, have found that the wide variations in rainfall from the mean in consecutive months and consecutive years constitute one of the most critical risks in their operations.

A program of research aimed at improvement of short- and long-range forecasts has been initiated by the sugar and pineapple industries of Hawaii in cooperation with the U. S. Weather Bureau. In the course of the work it has become clear that the investigations of Hawaiian climate in the past have been of such diverse character that a summary of present knowledge would be of assistance to those workers concerned with climatologic problems of these latitudes.

## STORM TYPES

A clear-cut definition of storm types is probably somewhat more difficult than it was thought to be in the past. Besides orographic rain resulting from lifting of the trade winds, Jones (1939) stressed the importance of what he called "cyclonic activity." He asserted that what is locally known as "kona weather" in Hawaii is associated with "cyclonic" or frontal activity. The word *kona*, interpreted as leeward, bears the connotation of winds from south or west (leeward with respect to the normal trade winds). Kona weather has also been described by Daingerfield (1921) and by Leopold (1948).

Jones pictured the periods of heavy rainfall as frontal passages of the temperate latitude type. Later work has shown that many disturbances, particularly in summer, are of the subtropical character as defined by Riehl (1945). During periods when the semi-permanent anticyclone of the eastern Pacific is strong, Hawaii derives rainfall from easterly waves—low pressure troughs moving toward the west in the trade wind current. Riehl (MS.) states that "weather conditions in winter are

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<sup>2</sup>Head, Department of Meteorology, Pineapple Research Institute, and Experiment Station, Hawaiian Sugar Planters' Association; Research Meteorologist, U. S. Weather Bureau, Honolulu; respectively.

marked by frequent interaction between wave troughs and ridges in the polar westerlies and tropical perturbations. Especially the larger amounts of rainfall over Hawaii seem to occur mainly in periods of such interaction, while uncomplicated passages of extratropical fronts account for many of the smaller rains. Interaction between disturbances of high and low latitudes apparently is the most potent rain-producing factor throughout the trade wind belt."

In describing cyclonic storms, Jones pictured the cloud types producing winter rains as comparable to middle latitude frontal cloud systems. This is true infrequently. Hawaii seldom experiences a complete overcast of altostratus or nimbostratus clouds. In a large percentage of storm periods, the cloud systems are more like those described by Riehl (1945) in the Caribbean. On rainy days over the ocean the masses of cumulus are larger and higher than usual, built up into congestus and, occasionally, cumulonimbus clouds. Patches of altostratus are usually associated with these cumulus masses, with occasional cirrus and altocumulus clouds. Over the islands, orographic lifting assists in cloud development, and the coalescing cumuli, viewed from below, often resemble nimbostratus. From afar it can be seen, however, that only segments of an island are under a complete overcast.

In summary, the rainfall usually comes from large but discrete cloud masses mostly of cumuliform type. A rainy day is characterized by increased size and number of cumuliform clouds. These changes result from horizontal convergence to the east (the rear) of the axis of an easterly wave and in association with a trough in a westerly current.

#### STORM TYPES IN RELATION TO RAINFALL

Studies of weather types correlated with rainfall amounts in Hawaii have been made by Huddleston (MS.) and by Wallen and Yeh (MS.). In both cases the authors used the Northern Hemisphere Surface Synoptic Chart

Series. Huddleston used the precipitation recorded at Honolulu and the CIT-AAF<sup>3</sup> classification system (1942). He also had available the 3 km. maps accompanying the Northern Hemisphere surface charts.

Huddleston showed that the best correlations with Honolulu rainfall were obtained with a type he called "No. 31," characterized by "purely zonal flow at the surface" with a series of cyclones moving eastward along the Aleutian chain. The 3 km. level is characterized by "weak circulation with the base of the upper trough extending as far south as the Hawaiian Islands . . ." Though his explanation is not very clear, his map gives the impression that the situation involves the passage over Hawaii of a polar trough of the type described by Riehl (1945). Huddleston's second important rain-producing type is his No. 22, "Meridional circulation . . . [with a] well developed Pacific High" positioned over the ocean 20° off the Oregon coast, and a "semi-stationary low center" northeast of Hawaii at about 30° N., 150° W. The abnormally high latitude position of the Pacific High is associated with a low index, and some frontal systems or troughs may move at relatively low latitudes over Johnston Island and Hawaii, stagnating in the semi-stationary trough northeast of Hawaii. The passage of these troughs over Hawaii would account for the correlation of the map-type with rainfall.

Wallen and Yeh (MS.) set up a surface map-type classification scheme which expressed the geographic relation of frontal systems and high pressure cells to Hawaii. The Hawaiian area was inspected on the daily Northern Hemisphere surface charts and the maps were classified for a 25-year period. The two main categories of their classification scheme were described as "anticyclonic" and "cyclonic." The former placed a high pressure cell NW or NE of Hawaii giving surface winds over the islands NE or ESE. The cyclonic situations were characterized primarily by westerly surface winds

<sup>3</sup> California Institute of Technology-Army Air Force.



over the islands with a low center to the NW, N, or NE. Their "anticyclonic" situations are clearly the normal or trade wind weather. They showed that the frequency of the two types varied inversely: the cyclonic was greatest in the December–February period while the anticyclonic was greatest in summer.

Because winter is usually the rainiest season and also the one when cyclonic storms are most frequent, Wallen and Yeh had expected to find a correlation between a yearly precipitation index for Hawaii and the frequency of cyclonic situations for the same year. This correlation, however, was not revealed by their data. They concluded that variations in trade wind rainfall are sufficiently important to mask any direct relation of total rain to the frequency of cyclonic storm types.

The importance of local convective clouds has generally been overlooked in view of the obvious importance of trade wind orographic rain. Leopold (1948) analyzed the time of day of rainfall occurrences on Oahu and Lanai and showed that the leeward or drier portions of these islands receive, primarily, afternoon rainfall. Stations on coasts exposed to the trade winds and those directly in the lee of the mountains receive nighttime rain predominantly, a characteristic of orographic rain in Hawaii (Loveridge, 1924; Jones, 1938). The afternoon maximum was interpreted as resulting from local convective clouds which build up over the drier areas with daytime heating of the ground surface.

Another characteristic type of rain in Hawaii is that of the "nalu storm" (Leopold, 1948), a summertime cumulus congestus or possibly cumulonimbus, which may produce short-duration, high-intensity rainfalls over leeward or dry portions of the islands. The nalu rains result from local convergence where the sea breeze meets the trade wind.

#### PROBLEMS AND TECHNIQUES IN ANALYSIS

In the analysis of map types, a difficulty which occurs in low latitudes is that the historic series of weather maps does not give sufficient

detail on the various low latitude disturbances which have been defined in recent years.

Riehl's studies in Puerto Rico (1945) can be applied with profit to synoptic analysis in the Hawaiian area. An important tool used by Riehl and others for synoptic analysis in these latitudes is a time cross section of winds plotted to the maximum observed height. Pressure and temperature data are also plotted at standard levels. Slight changes in winds, pressures, and temperatures will often show the passage at high levels of minor troughs which may go undiscovered or be poorly defined on the weather maps.

Using a similar type of chart, Stidd (MS.) noticed that in the winter months no rain fell in the drier localities of Hawaii as long as the trade winds were present in the lowest 2,000 or 3,000 feet. Each occurrence of rain was preceded by an almost total disappearance of the trade wind. A positive correlation between rainfall and surface pressure tendencies was also demonstrated, the rainfall occurring in conjunction with rising pressures. Situations in which the axis of the nearest high pressure cell was passing to the east of the station as it sloped toward the equator with height were more productive of rain than those situations in which the axis was passing to the west. This is in accord with general knowledge of the distribution of convergence and divergence about the high cell.

Another aid to synoptic analysis made use of the vast number of weather reports from airplanes flying Pacific routes (Stidd, 1948). This is essentially a graph of time versus distance along a given route, the plane reports being spotted in their appropriate positions. Points of minimum "delta value" (true altitude minus pressure altitude) were found to lie on nearly straight lines in the summertime. The positions of these lines were found to correspond to the positions of easterly waves and the slopes of the lines were a function of the speed of such waves. The full use of all pilots' reports is a time-consuming operation, however, and a thorough test of this method has not yet been made.

Mordy and Leopold (MS.) found highly significant correlation between trade wind rainfall on Oahu and the temperature at 300 mb. (about 30,000 feet msl.) on the Honolulu sounding. This is particularly interesting because trade wind rain falls from clouds whose tops ordinarily do not exceed 10,000 feet msl. Recent studies by the authors indicate that the 300 mb. chart is probably the most important tool in forecasting rainfall in the Hawaiian area.

#### GEOGRAPHIC DISTRIBUTION OF RAINFALL

Mean annual rainfall maps for the various islands in the Hawaiian group, which improve on the Oahu annual map of Voorhees (1928), are available in the Territorial Planning Board Report (1939). The only monthly isohyetal maps available are median rainfall maps for Oahu prepared by Halstead and Leopold (1948), based on an 11-year period, 1936-1946.

Tüllman (1936), in a study of rainfall distribution over the central and western Pacific, prepared mean annual rainfall maps for the Hawaiian islands of Kauai, Oahu, Maui, and Hawaii. His monthly and annual means were generally based on the 20-year period from 1905 to 1924. The records of those stations which did not coincide with that base period were adjusted. His data came from the published records in *Climatological Data*. Tüllman did the work in Germany and apparently did not have access to Voorhees' map.

Tüllman's isohyetal maps are sketchy, but his graphs of the annual march of rainfall at various stations are of interest. The mean rainfall for each month was plotted on a time-versus-precipitation graph for each station having the requisite records for direct use or adjustment to the 20-year base.

The Weather Bureau, in the publication *Climatological Data*, groups the stations of each island in geographic units selected primarily to divide windward from leeward stations. Oahu, for example, is divided into six areas. Using the stations within each of these geographic units, Tüllman compared qualitatively the curves showing the annual march of rainfall at each

station and grouped together the stations which had similar curves. This provided two or three groups within each geographic unit. Those stations lying in the same elevation zone had similar annual march curves.

It was unfortunate that Tüllman did not discard the arbitrary geographic units of the Weather Bureau and lump all stations having similar annual march curves. He would thus have been able to delineate, on various islands, zones which are similar in distribution of rainfall during the year. This would be one indication of similarity in rainfall processes. In a single given month there are large differences between the mean rainfall for each island; moreover, during a given storm, geographic units having apparently similar exposure may record widely different rainfall amounts. The problem of determining areas of similar rainfall processes is, therefore, not as simple as might be expected. Delineation of such areas is important in the problem of developing techniques for both short- and longer-term quantitative rainfall forecasts for various portions of each island.

Tüllman's group curves can be analyzed and consolidated to provide the recapitulation mentioned. Only moderate accuracy could be expected, however, because he did not publish the numerical rainfall data in tabular form with the curves. Quantities could be determined only as accurately as the small-scale curves could be read.

The most striking features of the annual march curves are the exceptionally low mean rainfalls for certain months. All groups of stations for Kauai show a low rainfall in February, as low as, and in some cases lower than, the mean for June. Yet January and March tend to be among the months of highest rainfall. This depression in February means is apparent to a lesser extent in all curves for Oahu, in those for the northeast slopes of west and east Maui, and for the northeast coast of Hawaii.

Radical increase in rainfall in November over October appears on the northeast coast of Ha-



waii at all elevations, and in the high rainfall zone of east Maui at elevations of 3,000–4,000 feet.

The northeast exposures of both east and west Maui and the high rainfall zone of eastern Hawaii show marked rainfall minima in June, October, and February. The same zones generally show sharp maxima in August, December, and April. Yet leeward Hawaii and Maui, all of Oahu, and all of Kauai exhibit no such striking behavior.

The 20-year period on which Tüllman based his mean rainfalls is sufficiently long to be considered fairly representative. The curves for certain of his groups might not have contained enough stations of long record and thus the adjustment procedure may have significantly affected their representativeness. Yet the consistency of these variations between certain areas lends credence to them.

An unpublished study by the authors (Stidd and Leopold, MS.), using more recent data, reaches conclusions which are in agreement with Tüllman's findings. This study discusses two individual components of Hawaiian rainfall and shows that their annual cycles are quite different. The cycle of cyclonic activity is shown to have a winter maximum and a summer minimum while the cycle of orographic activity is found to have a three-phase annual cycle with minima in June, October, and February. These minima correspond exactly to the minima of rainfall found by Tüllman in the very wet regions of Maui and Hawaii.

The study also shows that mean monthly rainfall distributions have the same type of pattern as the mean annual distributions, the only fundamental differences being in spacing and values of the isohyets. A quantitative statement of these two variables is shown to define adequately the rainfall distribution and magnitude for any mean month.

The study implies that the pattern of mean annual rainfall can, as an approximation, serve as the pattern for rainfall over any given period

of time, and quantitative daily forecasts of rainfall based on this approximation are now being made.

Because of the skewness of the frequency distribution of monthly rainfall values, the arithmetic mean is a poor statistic to represent normal values of Hawaiian data. The occurrence of abnormally wet months causes the mean rainfall values to be significantly greater than median values. Landsberg (MS.) showed that median monthly rainfall values for Hawaiian stations reach stability in a shorter period of record than do means. But he noted that for an island as a whole, "the pattern of isohyetal maps . . . if medians are used, shows no material difference in areal distribution compared to maps using mean-value isohyets. The difference is one of absolute values, not a shift in the location of drier or wetter areas."

The greatest monthly and annual values of precipitation are obviously in the mountain area. Annual means vary from 450 inches on Mount Waialeale to less than 10 inches on the lee side of Maui. Studying the Honolulu area, Voorhees (1928) found the correlation coefficient between mean annual rainfall values and station elevation to be only +.21; correlating annual mean with distance from the mountain crest gave a value of —.81. The maximum rainfall area in the Koolau Range on Oahu, average elevation 2,000 feet, lies about a mile leeward of the mountain crestline. The Koolau Range is long and narrow and is oriented perpendicularly to the trade wind.

The essentially conical-shaped mountain ranges of central Kauai and west Maui reach maximum elevations of about 5,000 feet. In both instances the maximum rainfall zones coincide with the maximum elevations. Yet on the higher (10,000–14,000-foot) conical mountains of Haleakala (east Maui), and of Mauna Loa and Mauna Kea (Hawaii), the zone of greatest annual rainfall is on the windward side at elevations of about 3,000 feet, a fact noted by both the Territorial Planning Board Report (1939) and Jones (1942). Leopold (MS.) attributes

the different elevations of maximum rainfall to convergence resulting from horizontal splitting of the trade wind by the higher mountains.

It is stated in the Planning Board Report (1939) that only in the Kona area (western portion of Hawaii) does the summer rainfall (May to October) exceed that of winter. However, Tüllman's curves, checked by current investigations of the authors, have disclosed that some of the wetter areas on Oahu and Hawaii have summertime maxima.

Correlations between the wind direction aloft (10,000 feet) and the geographic distribution of rainfall were made by Wallen and Yeh (MS.). Though their conclusions are tentative, they indicated that relative to the direction of wind at 10,000 feet the rainfall maxima appeared on the lee side of islands and the minima on the windward sides. Though this at first seems contrary to the expected orographic effects, Wallen and Yeh present a qualitative picture of distribution of convergence and divergence which might explain the observed rainfall pattern.

Riehl (MS.) studied 10 years of daily rainfall records at 21 rain gages in north central Oahu. He delineated four districts which approximately coincide with the areas known locally as Waimea, Waialua, Wahiawa, and Helemano. At the outset he defined "effective" precipitation as rain of 0.10 inches in a day at a given station. In summer 20 per cent of the total rainfall occurs in showers of less than 0.10 inches in a day and is, therefore, ineffective. In winter only a negligible amount is ineffective. Of the total *number of days* of rain, 40 per cent in winter and 60 per cent in summer are ineffective. For the remainder of his study, only "effective" rain was considered. He then defined a "rainstorm" as one which "in each of the four districts half or more than half of the stations received [effective] precipitation." He concluded that 80 to 90 per cent of the total precipitation occurs in "rainstorms."

Isohyetal patterns of mean monthly rainfall due to "rainstorms" show higher rainfall over

the mountains than over the plains. In other words, orographic lifting is an important factor determining rainfall distribution in general storms.

Riehl found that rainstorm precipitation is more evenly distributed from mountain to plain in summer than in winter.

#### MONTHLY AND ANNUAL VARIATIONS IN RAINFALL

Variations in yearly values of rainfall for Oahu stations were studied by Nakamura (1933). As an index of this factor he computed the ratio of standard deviation to mean annual rainfall for each of certain stations. Isopleths of this index showed that the smallest year-to-year variation occurred in the high rainfall zones of the mountains and the largest variations in the leeward, drier areas.

Landsberg (MS.) found that for 11 Oahu stations, every month of the year had had, in one individual year or another, the smallest monthly rainfall total in the year. As a measure of the skewness or asymmetry of the monthly rainfall frequency distributions he computed the value  $\frac{\text{median-mean}}{\text{mean}}$  for each of the 12 months,

at a given station. By averaging the ratios for the 12 months, each station would be represented by an index of asymmetry. These values for each of 22 Oahu stations plotted on a map showed that the greatest asymmetry occurred in lower leeward stations, and the least in windward and mountain stations. This is similar to the coefficient of variation computed by Nakamura and described above, and it checks his geographic distribution.

Another indication of the smaller variations in rainfall at higher stations is provided by Wentworth (1946), who studied the inter-station correlation of amounts of annual rainfall on Oahu. Annual rainfall values at various pairs of stations were expressed as ratios, year by year. Wentworth computed the mean ratio between pairs of stations as part of an analysis of the frequency distribution of these ratios.



The best correlated pairs of stations had a probable deviation from their mean ratio of less than 10 per cent. For those pairs having poorest correlation, the most probable deviation in a single year was 45 per cent. The best correlated pairs were found among the high rainfall stations, while the low rainfall stations showed the greatest deviations.

Wentworth's study is important also to students of hydrology. He showed how the inter-station correlations could be used to synthesize missing annual rainfall amounts at stations whose records are sufficiently long to establish the initial correlation. The method provides indices of reliability for such interpolated records and could be used on monthly as well as annual values.

Riehl (MS.) found a double maximum of effective precipitation in both summer and winter, as had Landsberg (MS.) and Tüllman (1936). Riehl attributes the minima in June and September to the seasonal shift of the sub-tropical ridgeline in the high troposphere. This ridge is centered over the latitude of Hawaii in June and September, having moved north in midsummer and southward again in the fall.

Secondary maxima of rainfall in winter are not due to a change in the number of storms, of which there is a single maximum in winter. Riehl concludes that at the beginning and end of the winter season there is the greatest possibility of interaction of summer-type tropical disturbances with the extra-tropical winter storms. This leads to the double maximum of rainfall in winter.

Riehl finds that 80 to 90 per cent of the total rain occurs in the general storms or "rainstorms." From this he concludes that present forecasting techniques which should allow the forecasting of these storms are sufficient to solve the main problems of agricultural forecasting for Hawaii.

The cyclic behavior of rainfall has been studied by a number of workers. Cox (1924) constructed an index of monthly rainfall values based on 10 stations and extending over 44 years. He concludes that a cycle of 3.7 years

appears to exist and is even stronger than the annual cycle.

Johnson (1946) analyzed yearly rainfall amounts at one station, Kualapuu, Molokai, by the method proposed by Alter (1937). Wentworth (1947) in reviewing this work concisely describes the method as "a process of finding that constant interval between pairs of years such that the average difference in rainfall between the two members of a pair is a minimum."

At Kualapuu, the 20-year periodicity was the strongest, and the 12-year cycle was second strongest. For the Honolulu record, a 14-year cycle appeared most probable with the exception of cycles of 36 years and certain others too close to the length of the 66-year record to be very reliable. Using the "Honolulu Rainfall Index" (the average of the percentages of the annual mean for 10 stations in the Honolulu area), Wentworth (1947) applied Alter's method to find the most probable cycles in the annual values of this series. He showed that the 16- and 20-year cycles were the most promising.

Working with the monthly values of rainfall at Waimanalo, Landsberg (MS.) showed by harmonic analysis that the annual variation is a wave which is not accidental. He decided that the existence of other periodicities in the data for that station was not probable.

The fact that the lengths of most probable cycles differ among stations or groups of stations in the islands markedly reduces the usefulness of, if not the confidence in, such cycles. Wentworth's analysis was the most practical. He showed that the average deviation of the "predicted" rainfall index from the actual can be reduced by using the 20- and the 12-year cycles. In individual years, however, the difference between actual value and the mean value was less than that between the actual and the value predicted by use of the cycles. Wentworth concludes, therefore, that "for practical purposes, any statistical, long-run gain is canceled by the evident risk of an aberrant estimate for a given year."

If, on the other hand, it can be shown that for certain specific purposes a reduction in average error of estimate outweighs the importance of very large errors in estimate for individual years, application of the technique should be considered.

The work of Solot (1948) has opened up new fields for the growth of longer-range forecasts for Hawaii. Having classified individual months on the basis of average rainfall for the Territory of Hawaii and on the average number of days of rain, he segregated monthly mean surface pressure maps for the Pacific area. The anomalies of mean pressure for individual months from the long-time average pattern were distinctly different for wet and dry months. Wet months are characterized by higher than normal pressure in the Aleutian area and a weak low in the mean pressure field over Hawaii. Dry months, on the other hand, have abnormally low pressure near the Aleutians and higher than normal pressure over the Hawaiian Islands.

Because there is some month-to-month persistency in the patterns most different from normal, these pressure anomaly patterns have some forecast value. Solot found that near-normal pressure distributions apparently have no significant persistence and the forecast value is dubious.

This distribution of anomalies fits the general knowledge of Hawaiian rainfall. Wet months, at least in winter, are characterized by a dislocation of the Pacific high and the admittance of cyclones to more southerly paths.

Riehl (MS.) interprets the import of Solot's correlations of pressure patterns and rainfall as follows: Mean monthly pressure patterns do not indicate deviations from average conditions which "would tend to raise or suppress rainfall throughout the month. They denote a basic state of the general circulation favorable or unfavorable for generation of a few potent disturbances."

Another possible forecast tool is provided by the work of Yeh (MS.). He found that there is some general relation between the latitude

of the belt of maximum west wind at 10,000 feet (the jet stream of Rossby) and precipitation in Hawaii. When the jet stream lies south of  $40^{\circ}$  N. Lat. on a given day, the probability of rainfall over Hawaii is small. Positions between  $50^{\circ}$  and  $60^{\circ}$  N. apparently are associated with higher rainfall probability.

#### WINDS

Most of the older studies of upper air data over the Pacific are of little significance in the development of forecast techniques. Beals (1927*b*) presented wind roses for various levels above Pearl Harbor, later extended to higher levels by Thomson (1928). The latter showed that the west winds, which surmount the low-level trade wind easterlies, reach lowest elevations in March and April on the average, while the height of the easterlies is greatest in May and June.

Beals (1927*a*) showed that the surface wind at Honolulu progressively changed in mean direction from northeasterly to a more easterly flow between 1905 and 1924. Wentworth (1949) has brought this study up to date and finds that in the last decade the earlier trend has been reversed, the mean winds gradually backing to a more northeasterly direction.

The diurnal patterns of wind have been discussed by Beals (1927*a*), Henry (1925), and Leopold (1948). In summary, sea and land breeze regimes control the wind direction in the lowest levels on the protected coasts of all the islands.

Leopold (1948) noted that the line along which the sea breeze meets the trade wind is associated with the development of a cloud line on Lanai, Molokai, and northeastern Hawaii. Diurnal changes in cloudiness in many areas are related to the development of sea and land winds. The regime is particularly apparent along the Hamakua (northeast) coast of Hawaii where drainage winds from Mauna Kea keep the slope clear at night; during the day the sea breeze reinforces the trades and causes an afternoon maximum of cloudiness.



At Honolulu and on the easterly coast of Oahu the surface wind is normally easterly at all hours with a maximum speed in the afternoon and a nocturnal minimum. Leopold (1948) relates this to surface stability at night. He showed that at Honolulu winds between 1,000 and 2,000 feet have a maximum speed at night. This, apparently, is caused by horizontal convergence as the subsidence temperature inversion reaches its minimum height at night.

#### CLIMATE IN RELATION TO CROPS AND VEGETATION

Maps of the areas covered by different vegetal associations have been compiled by Ripperton and Hosaka (1942).

There is evidence of change in vegetation in certain areas, the most prominent being noted in the Waimea area of Hawaii where many square miles formerly in heavy forest now constitute a grassland containing large amounts of an introduced cactus. A local wind storm, known as "mumuku," is said to have decreased markedly in frequency between 1830 and 1856. The change was attributed to the introduction of cattle and subsequent modification in vegetation (Anonymous, 1856 and 1926).

In a series of papers, Das (1928, 1931 *a,b*) analyzed the relation of monthly sequences of temperature and rainfall to the production and quality of sugar. High-quality cane juice was apparently correlated with high temperatures during the first summer after planting and with cooler weather in the winter prior to harvest. Rainfall should be relatively low during the winter season and relatively high during the summer to produce the best quality of cane. Das found that a wet August in the summer prior to harvest was strongly correlated with high yield.

#### BASIC DATA

Few areas of comparable size have the large number of rain measurements made in Hawaii. Approximately 900 rain gages, most of which are kept by sugar and pineapple plantations and

by cattle ranches, are currently installed. About three-fourths of these gages are read daily. The data from 205 are published as daily values in *Climatological Data*; in addition there are 79 stations for which monthly values only are published. A survey of basic rainfall data being collected currently has been made by Leopold, Burn, and Stidd (1948).

Surface wind observations are few except on the island of Oahu and the only upper wind data are collected by the Weather Bureau from Honolulu.

For studies of phenomena of the lowest 4,000 feet of the atmosphere, the location of the Honolulu Airport from which the Weather Bureau radiosondes are flown is poor. With respect to the trade winds the office is about 8 miles leeward of the Koolau Range, whose peaks in this vicinity reach 3,000 feet.

Forecasting at Honolulu is very dependent on reliable and continuous upper air observations at the existing ship stations and on Midway and Johnston Islands. Full use of pilot reports, particularly in summer, will probably become more essential as improved techniques develop.

#### DIRECTION OF FUTURE WORK

The strong geographic patterns of rainfall totals should make the development of a scheme for quantitative short-range rainfall forecasts relatively simpler than in many other places. On the other hand, significant differences between apparently similar areas on different islands loom large as potential difficulties. Four directions of work are necessary: (1) the definition of criteria for expressing the strength of pressure troughs locally affecting the Hawaiian Islands; (2) the correlation of these criteria with rainfall quantities; (3) inter-correlation of rainfall between different stations or localities; and (4) an improved understanding of the structure of the high troposphere and lower stratosphere.

To attain these ends certain groundwork is required. In connection with quantitative measures of the importance of various upper air

factors influencing rainfall, a series of well-analyzed upper air charts together with time-height sections of wind and radiosonde data must be collected. Past maps available at the Honolulu Weather Bureau office only partially fit this need. After teletype sequence data are destroyed, plotting of the necessary time-height sections is made difficult.

Correlation of rainfall values with the upper air data and inter-station correlation require better organization of the basic rainfall data. In January, 1948, a scheme for routine collection of all rainfall quantities in a centralized location was initiated by the Pineapple Research Institute and the Hawaiian Sugar Planters' Association Experiment Station.

The attainment of longer range forecasting techniques is apparently in sight as a result of Solor's work and that of the Extended Range Forecast Section of the U. S. Weather Bureau. For the best use of such forecasts the same problems of inter-station correlation are met, this time with monthly rainfall values. Month-ahead rainfall forecasts made by the Weather Bureau for Hawaii are now being tested by selected sugar and pineapple plantations.

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## The Status of Native Land Birds on Molokai, Hawaiian Islands

FRANK RICHARDSON<sup>1</sup>

MOLOKAI, the fifth largest of the Hawaiian Islands, is 38 miles long and about 10 miles wide. Its eastern half is high land running up to almost 5,000 feet in height. Some rather extensive areas of native forest still remain on the upper slopes, but introduced plants have displaced the native growth over large areas. In spite of the large area and the amount of cover, the rather intensive observations of the Hawaiian Bird Survey from 1935 to 1937 resulted in only a single record (Munro, 1944: 96) of a native land species on Molokai—the apapane (*Himatione sanguinea*). The survey covered large areas of native forest, chiefly in the east-central part of the island, where endemic birds had once been abundant. Munro thought he heard the song of the Molokai thrush (*Phaeornis obscura rutha*) in 1936 but was not certain. Richards (1946: 29) probably saw amakihi (*Chlorodrepanis virens wilsoni*), but this too is uncertain. Bryan (1908) was apparently the last ornithologist to observe and collect various native birds that have since become extinct or nearly extinct. He saw Perkins' mamo (*Drepanis funerea*), the crested honeyeater (*Palmeria dolei*), the Molokai creeper (*Paroreomyza maculata flammea*), and other native birds. Certain species, such as the ou (*Psittacirostra psittacea*) and the oo (*Acrulocercus bishopi*), were almost certainly extinct even then.

The survey of 1935–1937 appeared to indicate that nearly all native birds formerly found on Molokai were extinct. However, the survey did not cover certain parts of the island, espe-

cially isolated canyons and highlands on the northeast side. Consequently, David Woodside and I undertook a visit to this little-frequented region. Our chief purpose was to observe birds on Olokui Mountain, which towers over 4,600 feet above and east of Pelekunu Valley which was a favorite collecting area of the fabulously successful collectors of the late nineteenth century. Bryan, as far as we could determine, was the only ornithologist who had been up on Olokui, and he probably covered only a small part of it. We hoped that the mountain, because of its great encircling cliffs and the bordering, deeply cut Pelekunu and Wailau Valleys, had escaped most human influences and that native birds which had long since disappeared from other parts of Molokai might have survived there. Munro, who is more familiar than anyone else with Molokai birds, repeatedly mentions (1944) Olokui as the last possible refuge for endemic birds on Molokai.

Mr. Woodside and I, with Harold St. John and two botanical assistants, landed at the mouth of Wailau Valley on February 2, 1948. The next day we followed the seaward ridge of Olokui (Fig. 1), and ascended the mountain to a height of about 3,000 feet, cutting our way through the thick plant growth above approximately 1,500 feet. We established a base camp at 3,000 feet, and during the next 3 days made trips into the canyons on the east side of Olokui to within half a mile of its top. After descending the mountain we crossed the island by hiking up Wailau Valley, climbed the steep south wall to its 3,000-foot rim, and then made the more gradual descent to Mapulehu.

<sup>1</sup> Department of Zoology and Entomology, University of Hawaii. Manuscript received June 30, 1948.



We saw only two species of native birds on Olokui—the apapane and the amakihi—but their abundance was noteworthy. Although we covered probably less than 3 linear miles, we saw well over 100 apapanes. A few of these were very likely “repeats,” but pairing and territories, which would have led to seeing the same birds along the same route, were not detected. Groups of as many as five apapanes were seen. Some disappeared over Wailau Valley and others appeared to be flying to Olokui, which suggested the likely abundance of this species in the high native forest to the east of Wailau. Only five, or possibly eight, amakihis were seen, but all were found in the same region near the lower edge of the native forest. Individuals were seen here on both our ascent and descent of the mountain, which suggested a reasonable abundance of this species even though it is apparently restricted in range. One amakihi was collected for certain identification. It is interesting that Bryan (1908: 158, 162) considered the apapane

the most numerous species in 1907 and the amakihi the second most numerous.

St. John considers the forest of Olokui as perhaps the finest unaltered native stand he has seen in the islands. The accompanying photographs (Figs. 1–4) record typical views of this forest. Several species of lobelia and the ohia lehua (*Metrosideros collina*), the dominant tree, were blooming. The olapa (*Cheirodendron Gaudichaudii*) was another abundant tree species. However undisturbed the native forest may appear, and however suitable it may seem for several species of native birds other than those observed, it is certain that the vertebrate fauna has been greatly disturbed, presumably by introduced vertebrates. Two non-native bird species were present: the white-eye (*Zosterops palpebrosus japonicus*), in an abundance probably only slightly less than that of the apapane, and the Chinese thrush (*Trochalopteryx canorum*), heard twice but seen only once. It appears that the apapane and amakihi have estab-



FIG. 1. View down northeast ridge of Olokui Mountain to mouth of Wailau Canyon. Trees in foreground are chiefly ohia lehua (*Metrosideros collina*) with light-colored kukui (*Aleurites moluccana*) interspersed below.



lished a balance with these alien species, but the possible effects of the non-native forms on species not now extant can only be conjectured.

Non-native mammals may well have altered the ornithological picture considerably. One mongoose (*Herpestes griseus*) was seen far up on Olokui, suggesting that the species, which is difficult to see in dense forest, is probably common. One rat seen high in a tree was collected and identified as *Rattus rattus alexandrinus*. Others had been eating the bananas of a small cluster of plants hidden in the native forest. Even in 1907 Bryan found evidence that the mongoose was decimating the population of the ground-nesting dark-rumped petrel (*Pterodroma phaeopygia sandwichensis*). The rat may also be a serious enemy of ground-nesting birds and of many tree-nesting forms as well, since it is a good climber. Pellets of the Hawaiian owl (*Asio flammeus sandwichensis*) made up of rat remains were found at and below the lower edge of the native forest. This native predatory bird, which has been known in recent years from unforested parts of Molokai, could

rarely if ever obtain rats in the dense native growth of most of the mountain. Goats, although abundant on the lower open canyon sides, have penetrated the native forest less than one-fourth of a mile. Undergrowth, especially of the uluhe fern (*Dicranopteris linearis*), seems to hinder their further ingress. The goat seen highest on the mountain was immediately below ohia lehua trees where we first observed apapanes and amakihis. Goats had not yet markedly altered the native trees at this elevation, although the lower vegetation was much changed.

Various native birds (white-tailed tropic bird, black-crowned night heron, wandering tattler, and golden plover) were seen in Wailau Valley, but no endemic passerines were observed. Introduced birds seen were the Chinese dove, the mynah, and the white-eye. Little native vegetation remains in the lower part of the canyon but good stands of native growth were encountered on the steep south wall. Apapanes and amakihis were again seen here as



FIG. 2. Forest on Olokui Mountain. Large-leaved tree at left is alani (*Pelea clusiaefolia*). Fern in foreground is okupukupu (*Nephrolepis exaltata*). Dr. Harold St. John in foreground.



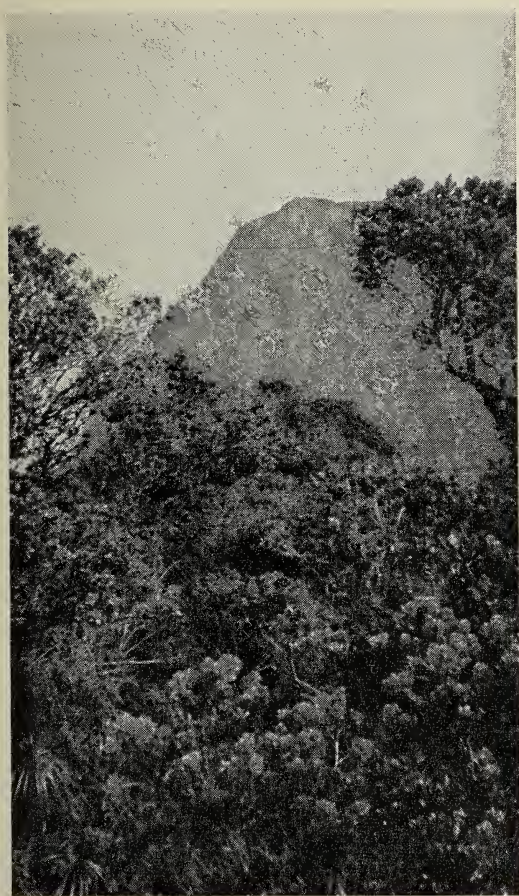


FIG. 3. Ohia lehua forest on Olokui looking across to east wall of Wailau Valley.

were white-eyes and a Pekin nightingale (*Leiothrix lutea*).

Even on Olokui our observations were not extensive enough to rule out the possibility of the existence of other native forest birds. The restricted area of rather uniform native habitat makes it seem likely that such birds, if they do exist, are very rare. However, the probably smaller number of individuals of tropical species and their not infrequently vagrant habits would necessitate a longer stay than ours before a reasonably sound conclusion could be reached. Woodside was almost certain he heard the song of an iiwi (*Vesteria coccinea*) from the south wall of Wailau Valley, so this species should be sought with particular care in the future.

A striking change was evident in the vegetation on the south rim of Wailau Valley. The southeastern half of Molokai slopes relatively uniformly and not very steeply to the south. Remnants of native forest cover some of the higher areas and it was chiefly here that the Hawaiian Bird Survey was conducted. However, on the broad slopes down to Mapulehu and on large areas on each side of our route, the native forest has virtually disappeared. Dead or scraggly ohia lehua trees represent what was apparently the dominant forest. Grasses have taken over much of the now-open slopes.

No sign of native birds was seen during our descent from the rim of Wailau, and undoubt-

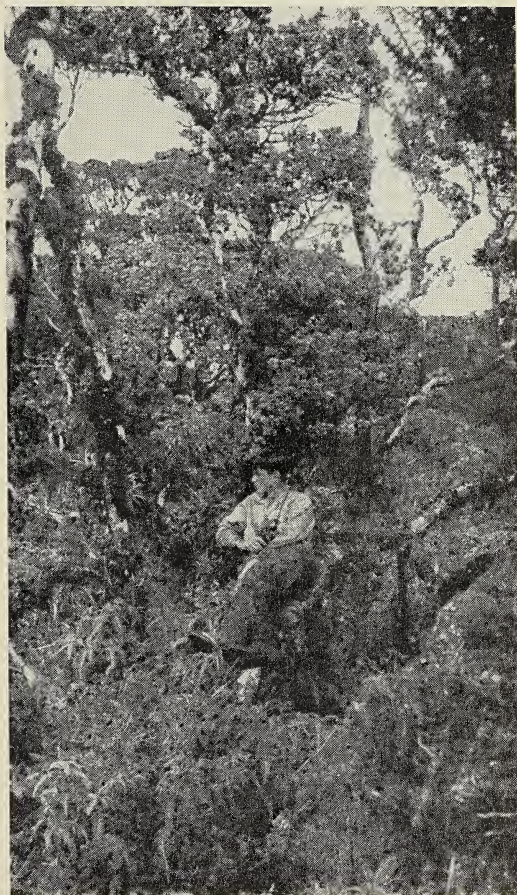


FIG. 4. Ohia lehua on Olokui. Fern at lower left is uluhe' (*Dicranopteris linearis*). David Woodside in tree.



edly none was to be expected under such changed conditions. Bordering canyons appeared to have relatively unchanged native cover, and certain rather extensive high forested areas exist in the Kahanui region. As indicated by the absence of native birds on the Survey, much of the eastern half of Molokai seems to be so cut up by areas of altered forest conditions that such birds have disappeared.

Our cursory inspection of southeastern slopes of Molokai does not justify detailed analysis of the factors which have caused major forest changes. It seems clear, however, that the large introduced vertebrates have been the primary cause. Deer, cattle, and pigs range or have grazed over much of the region. Although they are most likely to occur in more open areas, the deer and cattle have penetrated the deep boggy type of native forest and also the less dense ohia lehua forest where the slopes have not been too steep.

Our observations on Molokai indicate that the remaining native forest birds are rather closely restricted to the northeast parts of the island where unaltered forest areas are most extensive and continuous. Olokui Mountain and the sides of Pelekunu and Wailau Valleys probably include the major part of the range of these native birds. In these regions there has

been little or no penetration by large introduced mammals. It seems likely that the continued welfare of the remaining native birds rests in fair measure on not introducing these mammals into the parts of Molokai which they have not invaded. Pigs, deer, and cattle apparently do not now occur in Pelekunu and Wailau Valleys, but once in these valleys it seems apparent that they would work their way up the least precipitous slopes and irreparably alter the native forest.

Acknowledgment is made to the Division of Hydrography and to the Division of Fish and Game of the Territory of Hawaii, to the University of Hawaii, to the Hawaiian Sugar Planters' Association, and to the United States Army for their cooperation in making possible this trip to a very inaccessible region. The photographs were taken by Robert St. John.

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# A Taxonomic Revision of the Genus *Neraudia* (Urticaceae)

RICHARD S. COWAN<sup>1</sup>

## INTRODUCTION

THE GENUS *Neraudia* is in the family Urticaceae and is endemic to the Hawaiian Islands. It is found from about 1,600 to 4,000 feet altitude but is seldom represented by more than a few plants in any locality. The lack of a large volume of material, the difficulty of collecting plants of the genus (both conditions resulting from its rarity), and some nomenclatorial confusion have contributed to the lack of understanding of the group. Even now, after the collections and observations of the past 2 years, it is felt that several more years of collection and observation are necessary to furnish sufficient material for evaluating more clearly some of the taxonomic entities included below. Even on the island of Oahu, which has been the most widely explored botanically of any of the Hawaiian Islands, more study of this genus is needed.

*Acknowledgments:* Dr. Harold St. John, Chairman of the Department of Botany, University of Hawaii, suggested this genus as one in need of study and possible revision. He has directed my work and I wish to express my gratitude for his aid and guidance. I also wish to acknowledge the kindness of Marie C. Neal, Curator of the Bernice P. Bishop Museum Herbarium (Ho<sup>2</sup>), inasmuch as the following work could not have been accomplished had it not been for the material borrowed from the herbarium. I am likewise grateful to Otto Degener of Honolulu for the loan of his collection of

this genus. To the Royal Botanical Garden, Kew, England (K); the Herbarium of the University of California (UC); Gray Herbarium, Harvard University (GH); New York Botanical Garden (NY); Museum National d'Histoire Naturelle de Paris (P); Conservatoire et Jardin Botanique, Geneva (G), I wish to express my appreciation for the loan of material of earlier collectors. Finally, to the friends and associates, particularly K. Sakimura of the Pineapple Research Institute of Hawaii, who have searched and collected as intently as I, I express my gratitude. I am particularly indebted to Florence (Mekeel) Lambeth for making the fine drawings for this paper. Her keen sense of proportion and attention to detail, her unreserved spirit of cooperation, and her ability to make herbarium specimens appear as fresh material have been an important contribution.

## HISTORY OF THE GENUS

The genus *Neraudia* was published by Gaudichaud on March 6, 1830, in the botanical account of his first trip around the world on the "Uranie." He named the genus in honor of M. Néraud, a French lawyer and amateur botanist of Madagascar with whom he became acquainted during his visit to that island. Gaudichaud described and illustrated *Neraudia melastomaefolia* and described *Neraudia ovata* on the basis of material which he collected in the "Sandwich Islands." In 1851 he published a plate illustrating a third species, *Neraudia sericea*, without description, the material for the plate having been collected by Gaudichaud on his second trip, this time on the "La Bonite" voyage. The plate, in

<sup>1</sup> Graduate assistant, Department of Botany, University of Hawaii. Manuscript received July 20, 1948.

<sup>2</sup> The standard symbols proposed by J. Lanjouw (1939-1941) for each herbarium are shown after the name of each institution and these are used in the lists of collections examined to indicate where each collection is deposited.

spite of being rather diagrammatic and lacking accuracy in some details, must nevertheless be accepted as valid publication since it is a "plate with analyses," which, according to the International Rules of Botanical Nomenclature, constitutes valid publication prior to 1908 (Art. 44). In his *Généralités*, published in 1827 and occupying the first part of the volume on the botany of the voyage of the "Uranie," he mentioned three specific epithets. The first, *melastomaefolia*, he retained when he published the genus in 1830, but the second, *pyrifolia*, he evidently changed in favor of the third, *ovata*, before he published the description.

Meyen (1834–1835), in the section of his journal concerning his experiences in the Sandwich Islands, described several new species, one of which was supposedly a new species of *Neraudia*, *N. glabra*. He wrote that the natives called *N. melastomaefolia* "mamaku," which is essentially "mamake," the name now applied to *Pipturus* spp. In his original description and again in 1843, when he transferred his species to the genus *Boehmeria*, Meyen described the leaf margins as crenate. This is particularly significant in that there are no collections of *Neraudia* which show such leaf margins and it is very likely that Meyen did not have a *Neraudia*. For this reason, the name is here excluded (see discussion accompanying *N. melastomaefolia* var. *parvifolia* for more complete explanation). Hooker and Arnott, who studied the plants brought back from the Beechey Voyage, in 1832 transferred the two known species of *Neraudia* to the genus *Boehmeria*, pointing out that in their opinion the two genera were indistinguishable.

Endlicher in 1837 and Steudel in 1841 transferred the described species to *Boehmeria*. Weddell, however, in 1856 accepted the genus and recognized *N. melastomaefolia* and *N. sericea*, giving the latter its first description. *Neraudia ovata* he reduced to  $\beta$ -variety of *N. melastomaefolia*.

Wawra in 1874 accepted *N. melastomaefolia* and *N. sericea* without mention of *N. ovata*.

He described a forma *parvifolia* of *N. sericea* with a question mark. The question mark would seem to indicate either that he was not sure what *N. sericea* was or that he was not sure what rank his entity should have. It seems that he did not know to what the name, *N. sericea*, should be applied as he used it for a group occurring on Kauai (*N. kauaiensis*). The form which he described was later recognized by Hillebrand with a change of status and it is herein accepted. Word has recently been received from the director of the herbarium at Vienna, where Wawra's and Meyen's material was preserved, that the section of the herbarium including the Urticaceae was destroyed by fire during the recent war, so it is unlikely that their material will ever be available for study. Furthermore, in 1935 neither St. John nor the director of the herbarium was able to find the specimen which Wawra had used as a basis for his forma *parvifolia*.

Bentham and Hooker in 1880 accepted the genus and remarked simply that two or three groups occurred in the Sandwich Islands.

Hillebrand in 1888 accepted Gaudichaud's *N. melastomaefolia* listing *N. ovata*, *N. glabra*, *Boehmeria melastomaefolia*, and *B. glabra* as synonyms. The name *Neraudia sericea*, he used incorrectly, applying it to a variety of *N. melastomaefolia*. He then described a new variety of *N. melastomaefolia*, var. *Kauaiensis*, and transferred Wawra's forma *parvifolia* of *N. sericea* to *N. melastomaefolia*, raising it to varietal status. On the basis of a scrap of material collected by John Lydgate on the island of Kahoolawe, and of which no one has seen material since, he described a new species, *Neraudia Kahoolawensis*. Engler in 1893 accepted the genus noting "2–3 Arten auf den Sandwich-Inseln."

In 1944 Skottsberg described forma *truncata* of *N. melastomaefolia* based on Selling 3363 from the Waianae Range of Oahu. This name is treated here as a synonym of *N. melastomaefolia* var. *parvifolia*.



In the taxonomic portion of this paper I have attempted to discover what the older concepts were and how the names were applied by studying available plates, descriptions, and the types of some of the groups.

#### RELATIONSHIPS OF THE GENUS NERAUDIA

Taxonomists differ in their interpretation of the family Urticaceae but even if it is divided into four families, as is done by many workers, *Neraudia* is still most logically assigned to the segregate family Urticaceae. As may be seen in Table 1, *Neraudia* shows some of the characters which have been used to separate two of these families. To summarize the table: the genus shows two characters overlapping between the two families; three features in common with the Urticaceae; one feature characteristic of the Moraceae. The presence of this overlapping would seem to indicate that the lines separating the families are not particularly well-defined. The use of the milky sap character in the segregation is not worthy of the importance attached to it by some workers. Possibly the aggregate interpretation of the family with several tribes would be a more logical and valid one than that of several rather weakly delimited families.

To determine which genus of the Urticaceae *Neraudia* most closely approaches morphologically (in an attempt to establish relationships) I have made a relatively complete review of the treatment of the family by Weddell (1856–1857). In his key to the genera of the “Boehmerieae,” *Neraudia* is placed in a group with

*Cypholophus*, *Sarcochlamys*, *Touchardia*, and *Laurea*. Of these, *Cypholophus* seems to be the genus most similar to *Neraudia*. In *Cypholophus* a fleshy perigone develops at maturity but it invests the achene very closely, whereas the achenes of *Neraudia* are completely free, with considerable space between them and their perigones. The flowers of *Cypholophus* are borne in dense heads as contrasted to the very loose groups of individual flowers of *Neraudia*. I find that *Neraudia* (in Weddell's treatment) shows the greatest morphological similarity to a genus of the preceding section of the key, the genus *Pouzolsia*, rather than to any of those in the previously mentioned section. This is a large genus distributed throughout the tropics with nine species in the Indian area and three from the East Indies. Table 2 presents some of the similarities and dissimilarities between these two genera. A definite statement of the relationships of these genera cannot be made until material of *Pouzolsia* from the many localities where it occurs has been examined critically; it does seem, however, that there is rather close relationship between the two.

There is also considerable similarity in general habit, floral structure, leaf characters, and type of fruit in *Neraudia*, *Pipturus*, and *Boehmeria*, but the first is separable from the others by the accrescent, fleshy calyx which surrounds the achene when it is mature. The achenes of *Pipturus*, surrounded by the dried and shriveled calices, are imbedded in a white, insipid, fleshy mass in the leaf axils.

TABLE 1

RELATIONSHIPS OF *Neraudia* TO THE SEGREGATE FAMILIES MORACEAE AND URTICACEAE.

CHARACTER	URTICACEAE	MORACEAE	NERAUDIA
Sap	Watery	Milky	Milky
Phyllotaxy	Alternate or opposite	Alternate	Alternate
Fruit	Achene	Aggregate or multiple	Achene
Stamens	Folded inward	Folded inward or straight	Folded inward
Ovule	Erect	Pendulous	Erect
Embryo	Straight	Curved or spiral	Straight

DISTRIBUTION OF SPECIES AND VARIETIES

*Neraudia*, which is restricted to the Hawaiian Islands, is represented on most of the major islands—Kauai, Oahu, Maui, Molokai, Lanai, and Hawaii. With only one exception, the groups are restricted to one island or to one particular part of an island. The exception is *N. sericea*, which occurs on Maui, Lanai, and Molokai. The varieties of *N. melastomaefolia* occur on three islands, variety *pubescens* on Kauai, variety *pallida* on Maui, and the other four varieties on Oahu.

In the Waianae Range of Oahu a greater number of groups is found than in any other island locality, for in this region grow varieties *melastomaefolia* and *parvifolia* of *N. melastomaefolia* and both varieties of *N. angulata*. In the Koolau Range of Oahu are found two of the varieties of *N. melastomaefolia*—*uncinata* and *Gaudichaudii*. An examination of the "total number of groups per island" in Table 3 shows that the number of groups per island decreases progressively to the south and to the north of Oahu. From this observation it is postulated that the island of Oahu received the ancestral form which has given rise to the groups of this genus. Certainly the number of groups on Oahu

would indicate a considerable period of active speciation during which time propagules have been transported to most of the other islands with subsequent modification of the introductions.

Altitudinally, members of the genus range from 1,600 to 4,000 feet. They are found in extremely dry to wet situations. Most of the groups are collected in moist regions but *N. ovata* grows in very dry soil or in rough lava fields. *N. sericea* also has been collected (as far as can be determined from scanty data) in the lower xerophytic forests growing in dry soil or in lavic regions.

TAXONOMIC CHARACTERS USED IN  
CLASSIFICATION

As in the floras of most regions, in the Hawaiian flora are a number of genera the species of which have been shown to evidence extreme variability. Much of the variation in a population is undoubtedly due to genetical differences but a certain proportion must be due to the complex series of micro-climates which are characteristic of the Hawaiian Islands. Because of this variability it becomes difficult to arrive at characters which will delimit the populations.

TABLE 2  
A COMPARATIVE ANALYSIS OF THE GENERA *Neraudia* AND *Pouzolsia*.

CHARACTER	NERAUDIA	POUZOLSIA
Sex condition of flowers	Dioecious	Monoecious, rarely dioecious
Flower arrangement	Axillary, unisexual clusters	Axillary heads, spikes, or cymes; sexes mixed in same inflorescence
Staminate calyx	4-parted	3-4-5-parted
Stamens	Four	Three to five
Apex of perigone	0-4 toothed	2-4 toothed
Ovule	Erect	Erect
Pistillate calyx	Fleshly, free from achene	Greatly enlarged or scarcely changed
Habit	Shrub or small tree	Trees, shrubs, or herbs
Leaf arrangement	Alternate	Alternate or opposite
Leaf margin	Undulate, dentate, or entire	Dentate or entire
Venation of leaves	3-nerved	3-nerved
Cystoliths	Disciform	Disciform



*Neraudia* has been a problem of this sort and it is apparent that instead of very precise, definite, constant characters which operate throughout the genus, there is a tendency for differences to be expressed in sets of characters. Furthermore, a character which is constant in one group may prove to be quite variable in another. Each population is influenced by its own set of environmental factors and each has its own particular genetical makeup. These two sets of factors alone are enough to insure that the degree of variability and the organ affected may be quite different in each population.

Leaf shape has been used to distinguish some of the groups in this genus and is occasionally a usable character since some of the groups show tendencies toward particular leaf shapes. However, in most of the groups leaf shape exhibits so much variability that it is not satisfactory as a key character. In some groups ovate to elliptic leaves with intermediate shapes occur in the same collection; in such groups, at least, leaf shape is an unreliable character. Leaf size is expected to show some variation in all genera but in this genus the extremes of lengths and widths are often great in the same group. The shape of the base and of the apex of the leaves is often more constant but this is not a completely reliable key character either.

Vesture of the leaves has proved the most reliable character in the genus and is, I believe, genetical in nature. Even the quantity of pubescence present seems to be relatively constant; but it is the type of hair, distribution, posture, and orientation of the hairs that are used as key characters. The hairs are always simple but may be short and uncinata, longer and arcuate, curving and bending irregularly, or straight. In some groups the lower leaf surface is glabrous or sub-glabrous; in others the pubescence is restricted to the venation but in most groups this is not so. The pubescence on the upper leaf surface is always of the same type as that below but is more sparse and usually appressed. The consistency of the leaves varies somewhat, insofar as it has been possible to observe it in fresh and dried collections, but it is constant enough to be used in identifying some groups.

The venation of the leaves is of two general types and on this basis the genus is separable into two parts. If a leaf is held against a strong light the fine details of the venation are clearly discernible with or without magnification. Because of the prominence of the secondary vein branches the first type appears to be a coarse-meshed net within the intervals of the primary vein branches, whereas the second type, due to the equal or greater prominence of the tertiary

TABLE 3  
DISTRIBUTION OF SPECIES AND VARIETIES OF *Neraudia*.

	KAUAI	OAHU	MAUI	LANAI	MOLOKAI	HAWAII
<i>N. melastomaefolia</i>						
var. <i>melastomaefolia</i> .....	--	x	--	--	--	--
var. <i>uncinata</i> .....	--	x	--	--	--	--
var. <i>Gaudichaudii</i> .....	--	x	--	--	--	--
var. <i>pubescens</i> .....	x	--	--	--	--	--
var. <i>parvifolia</i> .....	--	x	--	--	--	--
var. <i>pallida</i> .....	--	--	x	--	--	--
<i>N. angulata</i>						
var. <i>angulata</i> .....	--	x	--	--	--	--
var. <i>dentata</i> .....	--	x	--	--	--	--
<i>N. kauaiensis</i>						
var. <i>kauaiensis</i> .....	x	--	--	--	--	--
var. <i>Helleri</i> .....	x	--	--	--	--	--
<i>N. ovata</i> .....	--	--	--	--	--	x
<i>N. sericea</i> .....	--	--	x	x	x	--
Total number of groups per island.....	3	6	2	1	1	1

branching gives the impression of a very fine-meshed net. The principal veins and their first branches may be strongly salient or only slightly raised. The leaves may be either palmately nerved or triplinerved and this character is of some use in distinguishing certain groups.

The flowers are of two sexes borne on separate plants. Flowers of either sex may be sessile or short-pedicelled but are constantly either one or the other. The calyx of all pistillate flowers is fused so that the ovary is loosely enclosed in the inflated calyx. The tip of this perigynium is always elongated into a beak through which the style passes. The stigma is filiform and covered more or less completely with stout stigmatic hairs which serve as receptive surfaces for the pollen. The pubescence on the exterior surface of the calyx is ordinarily of the same type and posture as that found on the lower leaf surface. After fertilization of the single, erect, basally attached ovule the ovary undergoes certain characteristic changes in form and becomes hard and bony. More striking though is the change in the calyx, which enlarges to many times its original size, becomes fleshy, and turns red at maturity. It is variable in shape and ranges in size from 3 or 4 millimeters to as much as a centimeter or more in height.

The achene characters are used to distinguish species and groups of subspecific rank. The dimensions and shape of the basal and apical portions of the achenes are usable characters but only if completely mature forms are available. The apical portion may be conic or depressed-conic and may be separated from the basal portion incompletely or completely by a deep or only slight constriction. The basal portion may be flattened or convex and its outer margin may be involute or plane.

The staminate flowers and pistillate flowers may be borne on pedicels. When they are so borne the pedicels are slender-filiform but because of their shortness (0.5–2.0 mm.) are most easily observed at nodes where flowers and fruits have been shed. Occasionally the scars of fallen sessile flowers become somewhat

swollen but differ from pedicels in their greater thickness and shortness.

The calyx of the staminate flowers consists of four navicular lobes which separate at maturity to release the four, opposite, inflexed stamens. The filaments are folded inward so that the connective is nearest the center of the flower. At maturity the filaments, when released by the opening of the calyx segments, snap outward explosively and at the same time the pollen is discharged in a small white cloud. From this method of pollen discharge and the presence of the feathery stigma described above, it may be safely postulated that the pollination agent is the wind since both of these mechanisms are adaptations for wind pollination. The staminate flowers have few distinctive characters other than different types of hair on the calyx and the consistency of the lobes.

#### TAXONOMIC CATEGORIES

Of all biological terms "species" is undoubtedly one of the most difficult to define in a manner which is satisfactory and acceptable to even a small group of taxonomists. The concept itself is reasonably clear but the problem of its definition must still be resolved by the individual worker. Each must decide what his basic criteria for the recognition of a species shall be and then attempt to apply his concept in the field as well as in the laboratory. Experience and contacts with other taxonomists will usually force certain modifications of the original concept so that the ultimate interpretation may be quite unlike that originally held. In this paper a species is interpreted as a population of individuals showing constant morphological differences distinct from those of other populations in the genus.

Varieties are considered to be units within the main specific population which show a character or characters peculiar to themselves but these differences are often overlapping to some degree, i. e., varieties lack the distinctness which characterizes the specific unit. The varietal category has not been used to replace



that of the subspecies nor is the category in any way related to the horticultural usage of the term. Some workers have advocated the abolition of the term "variety" and have used the argument that there is confusion in its usage in formal taxonomy and in horticulture. However, it is a category sanctioned in the International Rules and the "confusion" is mostly in the minds of the workers who advocate abolishing the term. A variety may arise by hybridization where two populations meet geographically, or it may be produced as a result of population changes induced by geologic or climatic isolation, although the origin in either manner may be obscured by the disappearance of intermediate forms. In general, it is assumed that varieties are incipient species.

Although subspecies and forms have not been recognized in the study of this group, it seems advisable to attempt a definition of them. The subspecies category seems to be applied best to groups of varieties with less than specific distinctness but more distinctness than a variety. Forms are taxonomic units (within either the specific or varietal population) which exhibit morphological differences of less significance than those shown by a varietal, subspecific, or specific group. Such entities appear sporadically within populations of higher categories. The difficulty lies in the recognition of forms, for unless extreme care is exercised each ecad may receive recognition as a form and be named and described as such. Forms are considered varieties in the embryonic state of differentiation.

#### SYSTEMATIC AND DESCRIPTIVE TREATMENT

##### Genus *NERAUDIA* Gaudichaud

*Neraudia* Gaudichaud, Freyc. Voy. Uranie  
Bot.: 500, 1830.

Erect, climbing, spreading, or vining shrubs or small trees with watery-milky or very milky sap; branches usually arcuate but sometimes erect and straight, branchlets green with pinkish tint at growing tip, pubescence very sparse to abundant, hairs erect or appressed, grayish or

whitish or almost hyaline; petioles 0.5–6 cm. long, terete, sparsely or abundantly pubescent, hairs erect or appressed, straight or irregularly bending and curving. Leaf blades 3–19.5 cm. long, 1.5–7 cm. wide, elliptic, lanceolate, oblance-elliptic, elliptic-ovate, ovate, slightly obovate, or oval, thin or membranous to thick-coriaceous, palmate or triplinerved; upper surface glabrous or with few to many erect or appressed hairs, cystoliths disciform, even with upper leaf surface, pulvinate, or strongly salient with rounded or sharply truncate apex (in dried material), lower surface glabrous or with few hairs largely restricted to venation, or with many erect or appressed hairs over entire lower surface, or with dense covering of erect to suberect, irregularly curving and bending hairs, or puberulent; principal veins and primary branches of veins slightly or strongly salient, margin entire, dentate, repand, or irregularly undulate; base cuneate, cuneate-decurrent, obtuse, or sub-cordate, apex abruptly acute to long-acuminate or tapering gradually into an acute or long-acuminate tip. Pistillate flowers sessile or on pedicels 0.5–2 mm. long, some flowers with subtending bract, calyx lobes fused into perigynium with tip drawn out into beak, perigynium pilosulose with few, ascending, appressed hairs or many erect hairs, beak flaring or narrowing upward, irregularly lacinate to four acute-toothed, to four acuminate-toothed, to three-toothed collariform, stigma 2–8 mm. long, receptive stigmatic hairs on all surfaces or one side lacking stigmatic hairs. Achene enclosed in accrescent, thin to thick-fleshy, smooth, or sharply angled and ridged calyx, achene 1–3.5 mm. tall, usually with distinct apical and basal portions, apical portion conic, depressed-conic, hemispheric, separated from basal portion by deep acute constriction or by very shallow or slight constriction or without definite, complete constriction, basal portion flat, depressed-convex, or convex, outer margin plane or involute, seed ellipsoid or ovoid, constricted in upper part or entire. Staminate flowers sessile or on pedicels 0.5–2.5 mm. long, four calyx segments cohering

in bud but separating at maturity, thin to thick, navicular, pilosulose, hairs appressed or erect, few to many, hairs straight or uncinat, 2–6 mm. long, 1–2 mm. wide, filaments 2–5 mm. long, folded inward in bud, strap-shaped, anthers two-celled, reniform, each sac 0.8–2 mm. long, 0.5–1 mm. wide.

#### KEYS TO THE SPECIES AND VARIETIES OF NERAUDIA

##### *Instructions for Use of Keys*

As collected, plants of this genus may be sterile, may have staminate flowers or pistillate flowers, may lack fruit, or may have both pistillate flowers and fruit. Because of this variety, keys which are intended to identify plants collected in any condition have been constructed. There undoubtedly will be collections which may prove troublesome but it is felt that the keys, if carefully used, will identify collections of the groups recognized. The heading of each key indicates the type of collection for which the key was constructed. In all cases the characters used in the keys apply to mature, dried, normally developed structures and it is important to recall this when attempting to use the keys. For example, the achene characters which are important appear sometimes only in the completely mature achenes.

In this study a dissecting microscope has been used and those who use the keys must do likewise. The necessary magnifications for studying pubescence and flowers in this genus are about 36–72 $\times$ , whereas pedicels or achene details can best be observed with about 12 $\times$  magnification. The details of the reticulation of the leaves have been used in the keys; the reticulation is most readily and accurately observed by holding a leaf against a strong light source, with or without magnification.

The length of the hairs has been referred to in some places as "short" or "long": the term "long" refers to hairs of about 1–2 mm. or longer; the term "short" refers to those considerably less than 1 mm. long.

The first key is based upon typical, full-

flowering material and should be used in attempting to identify such material only. Collections in the vegetative state or in a state of transition between vegetative activity and flowering should be identified by Key II.

##### *Glossary of Terms Employed*

**Basal portion**—applied to the lower expanded portion of the achene.

**Depressed-conic**—applied to the apical portion of some of the achenes which appear to have been depressed apically so that the sides are rounded and bulging.

**Interval**—the portion of a leaf blade enclosed by any degree of branching of the venation, e. g., a primary interval is that part of the leaf blade within a part of the primary branching.

**Perigynium**—the calyx of the pistillate flower fused into a bladder which surrounds the ovary.

**Pilosulose**—pilose, but with the hairs short.

**Primary branches**—first degree of branching of the principal veins.

**Principal veins**—midrib and two equally strong laterals.

**Puberulent**—covered with fine and short, almost imperceptible down.

**Sericeous**—covered with many shining, silky, appressed or sub-erect, straight hairs.

**Triplinerved**—principal veins diverging any distance above the leaf base.

#### KEY I

##### General Key to Species and Varieties of *Nerandia*

1. Lower leaf surface glabrous, subglabrous with only few hairs largely restricted to venation, or with long, evenly distributed, appressed or sub-appressed hairs. 2
  - Lower leaf surface evenly puberulent, sericeous, or pilosulose with more or less dense cover of irregularly curving and bending hairs ..... 7
- 2 (1). Flowers of one or both sexes all, or at least some, pedicelled; pedicels 0.5–2 mm. long ..... 3
  - Flowers of both sexes sessile ..... 5



- 3 (2). Lower leaf surface with many rather long, evenly distributed hairs. Uncinate hairs lacking on all plant parts.....*N. melastomaefolia* var. *Gaudichaudii*
- Lower leaf surface with few or no hairs except on veins; if present, in intervals and very short; uncinete hairs present on leaves and calices ..... 4
- 4 (3). Leaves and calyx lobes coarse, thick; venation on lower leaf surface markedly salient; leaves usually triplinerved. Apical portion of achene depressed-conic, basal portion thickened. Calyx of staminate flowers with about equal proportion of straight appressed and shorter, erect, uncinete hairs.....*N. melastomaefolia* var. *melastomaefolia*
- Leaves and calyx neither coarse nor thick; venation on lower leaf surface not very salient; leaves usually palmately nerved. Apical portion of achene usually conic, basal portion thin, often flat. Calyx of staminate flowers with all or most of the hairs short, erect, uncinete.....  
...*N. melastomaefolia* var. *parvifolia*
- 5 (2). Pubescence on lower leaf surface largely restricted to venation, primary intervals without long hairs. Outer margin of achene not involute..... 6
- Pubescence on lower leaf surface not restricted to venation, primary intervals with many long, appressed or sub-erect hairs distributed over entire surface. Outer margin of achene involute.....  
...*N. melastomaefolia* var. *pubescens*
- 6 (5). Secondary veins and smaller vein branches of lower leaf surface with many short, erect or sub-erect, uncinete hairs; lower leaf surface paler but not markedly pallid when dry.....  
...*N. melastomaefolia* var. *uncinata*
- Venation of lower leaf surface not as above, glabrous or sparsely pilosulose with few ascending, appressed hairs; lower leaf surface very pallid when dry.....  
...*N. melastomaefolia* var. *pallida*
- 7 (1). Lower leaf surface white- or whitish-sericeous, usually conspicuously viscid. Calyx of pistillate flowers distinctly angled, that enclosing mature achene thick-fleshy and with many fleshy ridges and angles ..... 8
- Lower leaf surface pilosulose with hairs irregularly curving and bending or lower leaf surface puberulent ..... 9
- 8 (7). Leaf margin always entire, pubescence on lower leaf surface appressed, oriented centripetally in primary intervals, mostly directed toward margin and producing a geometrically uneven sheen....  
.....*N. angulata* var. *angulata*
- Leaf margin completely dentate, partly dentate, or rarely entire; pubescence on lower leaf surface mostly erect or sub-erect but upper part of each hair somewhat arcuate, pubescence oriented much as in var. *angulata* but geometrically uneven sheen not marked .....  
.....*N. angulata* var. *dentata*
- 9 (7). Lower leaf surface puberulent. Outer margin of achene involute .....*N. ovata*
- Lower leaf surface with more or less dense cover of grayish pubescence, hairs irregularly curving and bending or almost straight. Outer margin of achene not involute ..... 10
- 10 (9). Leaf margin entire ..... 11
- Leaf margin irregularly undulate (only staminate flowers known) .....*N. kauaiensis* var. *Helleri*
- 11 (10). Apical portion of achene conic without deep constriction separating it from basal portion. Leaf base usually sub-cordate; secondary branching of veins forming the conspicuous reticulation in primary intervals .....  
.....*N. kauaiensis* var. *kauaiensis*

Apical portion of achene depressed-conic with deep constriction separating it from basal portion. Leaf base usually cuneate; tertiary branching of veins forming the conspicuous reticulation in primary intervals .....*N. sericea*

KEY II

For Identification of Non-fruitlet Pistillate or Sterile Plants

- 1. Secondary branching of veins forming conspicuous reticulation of leaf, that formed by the tertiary branching less conspicuous or obscure, giving the impression of a coarse-meshed net within the primary intervals ..... 2  
Tertiary branching of veins forming the conspicuous reticulation of leaf, that formed by the secondary branching not more conspicuous and often less conspicuous than that formed by the tertiary branching, giving the impression of a fine-meshed net within primary intervals ..... 14
- 2 (1). Calyx of pistillate flower angled. Lower leaf surface sericeous.... 3  
Calyx of pistillate flower not angled. Lower leaf surface not sericeous . 4
- 3 (2). Leaf margin dentate, partly dentate, or rarely entire. Pubescence on lower leaf surface mostly sub-erect except that upper part of each hair is somewhat arcuate .....*N. angulata* var. *dentata*  
Leaf margin always entire. Pubescence mostly appressed and directed toward margin, oriented centripetally in primary intervals producing a conspicuous geometrically uneven sheen .....  
.....*N. angulata* var. *angulata*
- 4 (2). Calyx beak attenuate apically. Lower leaf surface not obscured by pubescence (or if partly or completely obscured, leaf base sub-cordate or leaf margin irregularly undulate) ..... 5  
Calyx beak expanded apically. Lower leaf surface obscured by pubescence (if not, or only in-

- completely obscured, lower surface puberulent or lower surface markedly pallid when dry) ..... 13
- 5 (4). Lower leaf surface with little or no pubescence; when present, hairs largely restricted to principal veins and primary vein branches; infrequently very short hairs in vein intervals ..... 6  
Lower leaf surface generally pubescent, hairs not restricted to veins but generally distributed over entire surface ..... 9
- 6 (5). Flowers all, or at least some, pedicelled; pedicels slender, 0.5–2 mm. long, often persistent on sterile plants recently fertile .... 7  
Flowers all sessile ..... 8
- 7 (6). Leaves thin, palmate; apex abruptly acute to acuminate; base often obtuse or sub-obtuse. Calyx lobes thin .....  
...*N. melastomaefolia* var. *parvifolia*  
Leaves thick, usually triplinerved; apex evenly acute to acuminate; base usually cuneate. Calyx lobes thickish, particularly at tips...*N. melastomaefolia* var. *melastomaefolia*
- 8 (6). Lower leaf surface with few to many erect or sub-erect, very short, uncinete hairs on venation other than principal veins and primary branches; paler below when dry but not markedly pallid. Leaf apex evenly acuminate ...*N. melastomaefolia* var. *uncinata*  
Lower leaf surface without uncinete hairs, entirely glabrous or with few, appressed hairs on principal veins; when dry, markedly pallid below. Leaf apex usually abruptly acuminate .....  
....*N. melastomaefolia* var. *pallida*
- 9 (5). Leaves with dense covering of irregularly curving and bending, erect hairs on lower leaf surface, or hairs almost straight ..... 10  
Leaves without above type of pubescence but with few to many long, evenly distributed, ascending, appressed or sub-erect hairs ..... 12



- 10 (9). Leaf margin entire ..... 11  
 Leaf margin irregularly undulate  
 (only staminate plant known) ..  
 ..... *N. kauaiensis* var. *Helleri*
- 11 (10). Leaf base usually rotund, sub-  
 cordate or obtuse. On upper leaf  
 surface at junction of principal  
 veins, tuft of hair always erect.  
 On veins of lower leaf surface,  
 hairs erect, irregularly bending,  
 or almost straight .....  
 ..... *N. kauaiensis* var. *kauaiensis*  
 Leaf base not rotund or sub-cordate,  
 usually cuneate. On upper leaf  
 surface at junction of principal  
 veins, tuft of hair appressed. On  
 veins of lower leaf surface, hairs  
 ascending, mostly appressed, and  
 nearly straight ..... *N. sericea*
- 12 (9). Leaves usually palmately nerved. .  
 . . *N. melastomaefolia* var. *pubescens*  
 Leaves usually triplinerved .... *N.*  
*melastomaefolia* var. *Gaudichaudii*
- 13 (4). Leaves elliptic or oblance-elliptic,  
 entirely glabrous or with few as-  
 cending, appressed hairs on mid-  
 rib of lower leaf surface; when  
 dry, lower leaf surface markedly  
 pallid .....  
 ..... *N. melastomaefolia* var. *pallida*  
 Leaves not as above, with dense  
 covering of erect, irregularly  
 curving and bending hairs on  
 lower leaf surface. .... *N. sericea*
- 14 (1). Lower leaf surface puberulent, hairs  
 very short, and fine, almost  
 hyaline ..... *N. ovata*  
 Lower leaf surface densely pilosulose,  
 hairs whitish or grayish and  
 longer (more than 0.8 mm.)  
 ..... *N. sericea*
- 3 (2). Leaf margin dentate, partly dentate,  
 or, rarely, entire. Pubescence on  
 lower leaf surface sub-erect, hairs  
 mostly arcuate in upper part, di-  
 rected mostly toward margin,  
 geometrically uneven sheen on  
 lower surface not marked .....  
 ..... *N. angulata* var. *dentata*  
 Leaf margin always entire. Pubes-  
 cence on lower leaf surface  
 strictly or mostly appressed and  
 oriented centripetally in primary  
 intervals and producing a marked  
 geometrically uneven silvery  
 sheen .... *N. angulata* var. *angulata*
- 4 (2). Outer margin of basal portion of  
 achene not involute ..... 5  
 Outer margin of basal portion of  
 achene involute ..... 11
- 5 (4). Apical portion of achene de-  
 pressed-conic or hemispheric ... 6  
 Apical portion of achene not de-  
 pressed-conic or hemispheric but  
 more or less conic with blunt or  
 sharp tip ..... 10
- 6 (5). Apical portion separated from  
 basal portion by deep transverse  
 constriction. Lower leaf surface  
 densely pilosulose, hairs erect, ir-  
 regularly curving and bending ..  
 ..... *N. sericea*  
 Apical portion separated by only  
 slight, obtuse constriction from  
 basal portion or lacking definite,  
 complete constriction. Lower leaf  
 surface not densely pilosulose,  
 hairs when present appressed to  
 sub-erect ..... 7
- 7 (6). Lower leaf surface with many  
 rather long, evenly distributed  
 hairs over entire surface .... *N.*  
*melastomaefolia* var. *Gaudichaudii*  
 Lower leaf surface with hairs mostly  
 restricted to veins, if in intervals,  
 hairs very short ..... 8
- 8 (7). Leaves thick, often triplinerved;  
 veins very strongly salient below.  
 Flowers of both sexes with pedi-  
 cels; calices thick, particularly at  
 tips of lobes of staminate calyx  
 ..... *N.*  
*melastomaefolia* var. *melastomaefolia*

## KEY III

For Identification of Pistillate Plants with Flowers and Fruit

1. Calyx beak attenuate apically ..... 2  
 Calyx beak expanded apically ..... 13
- 2 (1). Calyx of flower angled; calyx of  
 mature fruit very thick-fleshy,  
 sharply ridged, and angled. Lower  
 leaf surface sericeous ..... 3  
 Calyx of flower not angled; calyx of  
 mature fruit not thick-fleshy,  
 sharply ridged, or angled ..... 4

- Leaves not thick, usually palmate; venation not strongly raised below. Flowers sessile; calices thin ..... 9
- 9 (8). Many very short, erect or sub-erect, uncinuate hairs on veins other than principal veins and primary branches. Apical portion of achene depressed-conic. Leaves drying paler below but not markedly pallid .....  
... *N. melastomaefolia* var. *uncinata*  
No uncinuate hairs present on lower leaf surface. Apical portion of achene hemispherical. Leaves drying markedly palid below .....  
... *N. melastomaefolia* var. *pallida*
- 10 (5). Flowers of both sexes with slender pedicels, 0.5–2 mm. long. Leaf base very often obtuse or sub-obtuse, sometimes cuneate. Very few hairs on lower leaf surface and these restricted for most part to venation. Staminate calyx with all or almost all hairs erect to sub-erect, uncinuate .....  
... *N. melastomaefolia* var. *parvifolia*
- Flowers of both sexes usually sessile, staminate flowers sometimes with short pedicels. Leaf base rotund, usually sub-cordate. Lower leaf surface with many erect, irregularly curving and bending or almost straight hairs covering entire surface. Staminate flowers pilosulose, hairs many, erect to sub-erect, ascending .....  
... *N. kauaiensis* var. *kauaiensis*
- 11 (4). Lower leaf surface pubescent. Calyx of staminate flowers with most hairs straight ..... 12
- Lower leaf surface glabrous or very sparsely pilosulose, few ascending, appressed hairs on venation. Calyx of staminate flowers with all or most hairs short, erect, uncinuate .....  
... *N. melastomaefolia* var. *parvifolia*
- 12 (11). Lower leaf surface pilosulose, hairs evenly distributed, ascending, appressed or sub-erect. Achene 2.5–3.5 mm. long, averaging 3 mm. long; apical portion conic, without definite, complete constric-
- tion from raised basal portion. Calyx surrounding mature achene, about 6 mm. long when dry  
... *N. melastomaefolia* var. *pubescens*
- Lower leaf surface puberulent, hairs erect or sub-erect. Achene 2–3 mm. long, usually 2 mm. long; apical portion depressed-conic, separated from depressed-convex basal portion by deep, obtuse or acute constriction. Calyx surrounding mature achene 4 mm. long or less ..... *N. ovata*
- 13 (1). Lower leaf surface glabrous or with very few hairs on principal veins. Calyx sparsely pilosulose, hairs few, ascending, appressed. Lower leaf surface drying markedly pallid ... *N. melastomaefolia* var. *pallida*
- Lower leaf surface puberulent or pilosulose with very many erect or sub-erect, irregularly curving and bending hairs. Calyx densely pilosulose, hairs appressed or sub-erect. Lower leaf surface not drying markedly pallid ..... 14
- 14 (13). Outer margin of achene involute, constriction separating apical and basal portion usually obtuse. Puberulent on lower leaf surface ..... *N. ovata*
- Outer margin of basal portion of achene plane, constriction separating apical portion usually deep and acute. Lower leaf surface with dense covering of grayish, irregularly curving and bending hairs ..... *N. sericea*

KEY IV

For Identification of Staminate Plants

1. Lower leaf surface sericeous ..... 2  
Lower leaf surface glabrous or pilosulose ..... 3
- 2 (1). Leaf margin entire; pubescence on lower leaf surface strictly or mostly appressed, centripetally oriented in primary intervals, producing a geometrically uneven silvery sheen .....  
..... *N. angulata* var. *angulata*
- Leaf margin dentate, partly dentate, or rarely entire; pubescence on lower leaf surface sub-erect, hairs



- straight except arcuate apically, mostly centripetally oriented but geometrically uneven sheen less marked . . . . *N. angulata* var. *dentata*
- 3 (1). Hairs on calyx lobes all or mostly straight . . . . . 4
- Hairs on calyx lobes all or almost all short, erect, uncinat; occasionally a few longer, straight, appressed hairs on margins . . . . .
- .. *N. melastomaefolia* var. *parvifolia*
- 4 (3). Few to many short, erect, uncinat hairs present on calyx mixed with numerous longer, straight hairs. . . . . 5
- No uncinat hairs on calyx lobes (or staminate flowers unknown) . . . . . 8
- 5 (4). Lower leaf surface with few hairs only, largely restricted to venation . . . . . 6
- Lower leaf surface with many hairs over entire surface . . . . . 7
- 6 (5). Flowers sessile; calyx lobes thin. Leaves thin, usually palmate; veins not very strongly raised below; many short, erect or sub-erect, uncinat hairs on secondary and smaller vein branches . . . . .
- .. *N. melastomaefolia* var. *uncinata*
- Flowers usually pedicelled; calyx lobes thick, especially at tips. Leaves thick, often triplinerved; veins very strongly salient below; uncinat hairs, if present, scattered indiscriminately on lower leaf surface . . . . . *N. melastomaefolia* var. *melastomaefolia*
- 7 (5). Calyx lobes membranous; lower leaf surface puberulent . . . . . *N. ovata*
- Calyx lobes thin but not membranous; lower leaf surface densely pilosulose, hairs white or grayish, irregularly curving and bending . . . . . *N. sericea*
- 8 (4). Lower leaf surface with many hairs; not drying very pallid below . . . . . 9
- Lower leaf surface with few or no hairs; drying very pallid below (staminate flowers unknown) . . . . .
- .. *N. melastomaefolia* var. *pallida*
- 9 (8). Leaf margin entire . . . . . 10
- Leaf margin irregularly undulate . . . . .
- .. *N. kauaiensis* var. *Helleri*
- 10 (9). Leaf base usually rotund, sub-cordate; pubescence on lower leaf surface erect, more or less irregularly curving and bending. . . . .
- .. *N. kauaiensis* var. *kauaiensis*
- Leaf base cuneate; pubescence on lower leaf surface appressed or sub-erect, entirely straight . . . . . 11
- 11 (10). Calyx usually over 4 mm. long, averaging 5 mm. long. Leaves palmately nerved . . . . .
- .. *N. melastomaefolia* var. *pubescens*
- Calyx 3–4 mm. long, averaging less than 4 mm. Leaves usually triplinerved . . . . . *N. melastomaefolia* var. *Gaudichaudii*
- Neraudia melastomaefolia** Gaudichaud, Freyc. Voy. Uranie Bot.: 500, pl. 117, 1830.
- Boehmeria melastomaefolia* (Gaud.) H. & A., Bot. Beechey Voy. 2: 96, 1832.
- Boehmeria melastomaefolia* (Gaud.) Endl., Wien Mus. Naturgesch., Ann. 1: 165, 1836.
- Boehmeria melastomaefolia* (Gaud.) Steudel, Nom. Bot. 2: 192, 1841.
- Shrub or small tree up to 6 m. tall, usually shrub less than 4 m. tall, main stem 1–5 cm. in diameter at base. Upper branchlets pilosulose, with few to many erect or appressed hairs, branchlets arcuate, lax, and pendent or erect. Petioles 1–5.5 cm. long, glabrous or pilosulose with few to many erect or appressed hairs. Leaf blades 4–19.5 cm. long, 1.5–7 cm. wide, elliptic, oblance-elliptic, lanceolate, elliptic-ovate, ovate, or oval, thin to thick, chartaceous or coriaceous, palmate or triplinerved; upper surface glabrous or sparsely pilosulose with few appressed, ascending hairs, lower surface glabrous or pilosulose, hairs few to many, appressed or sub-erect, ascending, restricted to venation or evenly distributed over lower leaf surface, and none to many shorter erect or sub-erect, uncinat hairs; principal veins and primary branches slightly to markedly salient below; margin entire, base cuneate or cuneate-decurrent to obtuse or sub-obtuse or slightly sub-cordate, leaf tip gradually or abruptly tapering into an acute

or acuminate or long-acuminate apex. Pistillate flowers sessile or with filiform pedicels 0.5–2 mm. long; calyx pilosulose, with few ascending, appressed hairs, and with or without some shorter, erect, uncinat hairs; beak usually attenuate apically, sometimes expanded, four-toothed at apex; stigma 2–8 mm. long, receptive on all surfaces or stigmatic hairs absent on one side. Achene 1.0–3.5 mm. long, apical portion sharply conic to depressed-conic, separated from basal portion by slight or incomplete constriction or without constriction, basal portion flattened, depressed-convex or convex, 2–3 mm. in diameter, plane or involute at outer margin; seed ellipsoid or ovoid. Staminate flowers sessile or pedicelled, with four navicular, acutely or acuminate tipped lobes, 4–6 mm. long, 1.5–2.0 mm. wide, pubescence of lobes mostly straight, ascending, appressed or mostly erect or sub-erect uncinat hairs; pistil rudiment 0.3–2.0 mm. long, filaments 2.5–5.0 mm. long, 0.5–1.0 mm. wide, connective swollen-fleshy or unswollen; anthers reniform, 1.5–2.0 mm. long, 0.8–1.0 mm. wide.

The subspecific entities which comprise this species are distinct enough to be considered varieties but to accord them higher rank is, I believe, without justification. I feel that species should show constant morphological characters with no or few intermediate forms whereas varieties very often have such intermediate forms. The varieties *melastomaefolia*, *uncinata*, *pubescens*, and *Gaudichaudii* are superficially similar but variety *parvifolia* has a different aspect.

Hillebrand (1888) included all the groups which he knew in the one species, *N. melastomaefolia*, with a variety, *parvifolia*. This variety was, as Hillebrand's citation shows, a transfer of Wawra's forma *parvifolia* of *N. sericea* (as applied by Wawra) to *N. melastomaefolia*. The transfer is herein accepted and the name applied to one of the varietal groups.

Certain inaccuracies in Gaudichaud's plate have become apparent on examination of his material. The leaves are illustrated as palmate with blunt apices, but the leaf tips in his ma-

terial are sharp and most of the leaves are triplinerved to some degree. The flowers on the pistillate branch of his habit sketch are strikingly similar to those of *Pipturus* and I believe that material of this genus was used for this part of the plate. Gaudichaud's artist shows stipules which are interpetiolar with the appearance of thorns rather than intrapetiolar, membranous structures. The bract-like structure at the base of his young pistillate flower is not uniformly present. The margin of the apex of the calyx neck is actually toothed rather than entire, and the fleshy calyx surrounding the achene is depressed-globose instead of convex. The achene is not stalked and is attached to the calyx on the ventral surface except at the outer margin. The seed is represented in his plate as having a constriction and the seed cavity as extending to the apex of the achene but neither is true. The staminate flowers are really oblong-elliptic rather than globose and the tips of the calyx lobes are much thicker than illustrated.

*Neraudia melastomaefolia* Gaud. variety *melastomaefolia* Cowan, *var. nov.*

Fig. 1

*Neraudia melastomaefolia* Gaud., Freyc. Voy. Uranie Bot.: 500, pl. 117, 1830.

*Description of Gaudichaud's material:* Upper branchlets with many ascending, appressed hairs. Petioles 1.0–4.5 cm. long with few to many ascending, appressed hairs. Leaf blades 8.5–12.0 cm. long, 2.5–4.5 cm. wide, narrow elliptic to oval, thick, mostly triplinerved, glabrous above, lower surface with few ascending, appressed hairs on principal veins, margin entire, base cuneate-decurrent, or only cuneate, apex evenly long-acuminate, principal veins very strongly raised on lower leaf surface. Pistillate flowers on slender pedicels 0.5–2.0 mm. long; calyx with many ascending, appressed hairs and some erect, uncinat hairs; beak attenuate apically; stigma non-receptive on one side. Staminate flowers on pedicels 0.5–1.5 mm. long; calyx with both short, erect, uncinat hairs and longer straight, ascending, appressed hairs, lobes thick,





FIG. 1. *Neraudia melastomaefolia* Gaud. var. *melastomaefolia* Cowan. a-g, Pistillate plant: a, habit (Type); b, one node (Type); c, portion of lower leaf surface (Type); d, young flower (Type); e, mature calyx enclosing achene (Frederick 207); f, long section through mature calyx and achene (ibid.); g, external view of achene. h-j, Staminate plant: h, habit (Gaudichaud); i, young flower (St. John 22568); j, mature flower (ibid.).

especially at tips. No mature achenes present.

*Description of all material examined:* Spreading shrub 2–6 m. tall, about 3 cm. in diameter at base; upper branchlets pilosulose with many ascending, appressed hairs. Petioles 1.0–4.5 cm. long, averaging about 2 cm. long, pilosulose with many appressed, ascending hairs. Leaf blades 6–13 cm. long, 2.5–7.0 cm. wide, averaging 9 cm. long, 4.5 cm. wide, narrow elliptic, elliptic-ovate, oval, or slightly obovate, thick, sub-coriaceous or coriaceous, very often tripinnately nerved, above glabrous, below sub-glabrous with only few straight, ascending, appressed hairs mostly restricted to veins, sometimes with very short, scattered hairs in intervals; margin entire, base cuneate and decurrent or sub-obtuse, apex acute or acuminate, tip of apex sharp or blunt, principal veins very strongly raised. Pistillate flowers with pedicels 0.5–2.0 mm. long; calyx sub-glabrous with very few ascending, appressed hairs; beak attenuate apically, apex with four acute or acuminate teeth; stigma 2–3 mm. long, one side usually lacking receptive stigmatic processes. Achene 2.0–2.5 mm. long, averaging 2 mm., apical portion depressed-conic, separated from basal portion by abrupt obtuse constriction or without obvious constriction, basal portion smooth, thick, outer margin plane, 2.5–3.0 mm. in diameter, seed ovoid. Staminate flowers with pedicels 0.5–2.0 mm. long; calyx lobes thick, particularly at tips, pilosulose with many ascending, appressed hairs and with or without some erect uncinulate hairs, lobes 3–5 mm. long, 1.5–2.0 mm. wide, apex acute or acuminate; filaments 3.5–5.0 mm. long, 0.5–1.0 mm. wide, tapering at apex into broader, fleshy, swollen connective; anthers 2 mm. long, 1 mm. wide.

*Type:* Gaudichaud, "In insulis Sandwichensibus, cum sequente (alt. 350–400 hex.)." (In Sandwich Islands, altitude 1,500–2,400 feet.) (Deposited in Museum National d'Histoire Naturelle de Paris [P].)

*Range:* Island of Oahu, Waianae Range, moist regions, 2,000–3,450 feet altitude.

#### *Specimens examined*

*Data complete:* Haleauau Gulch, Mt. Kaala, *St. John* 22269, 22270 (Ho); Mt. Kaala, *Degener* 18190 (NY); Mt. Kaala, *Cowan and St. John* 333 (Ho); Puu Kalena, *St. John* 22568 (Ho); Puu Kalena, *Donaghho* (Ho); Hapapa Gulch, *Russ* (Ho); Kanehoa, *Frederick* 207, 208, 209, 210 (Ho); Kanehoa, *Cowan* 1054, 1057 (Ho); Makaha Valley, *Forbes* (Ho); Oahu, Waianae, *Faurie* 515 (P, Ho).

*Data not complete:* Honolulu, Sandwich Islands, *Hillebrand* (K); Oahu, *Seeman* 2260 (G, K, Ho); *Mann & Brigham* 220 (GH, G, Ho); Woahoo, *Macrae* (K); *Gaudichaud* 208 (Bonite Voyage) (G); *Remy* 197, Maui (data very questionable) (P).

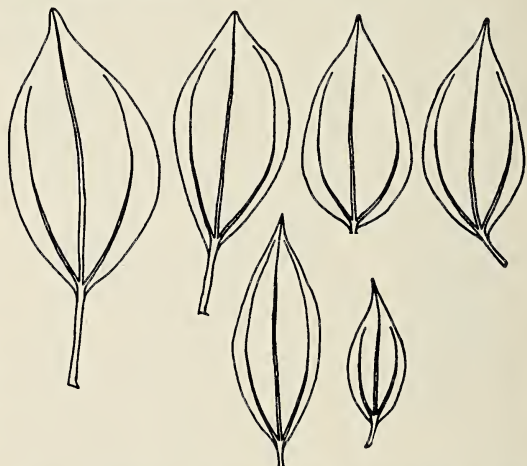


FIG. 2. Outlines of leaves to show variation in leaf shape and in venation in *Neraudia melastomaefolia* Gaud. var. *melastomaefolia* Cowan (approx.  $\frac{1}{3}$ ).

This group seems in several ways to be intermediate between varieties *uncinata* and *parvifolia* and may have arisen as a result of hybridization between the two groups. The pedicels which characterize this group link it to variety *parvifolia* but the leaf shape, size, general aspect, and depressed-conic apex of the achene link it to variety *uncinata*. The occasional presence of some uncinulate hairs scattered indiscriminately on the lower surface of the leaves further shows some relationship to variety *uncinata*. Plants of this group may be identified by the pedicelled flowers and by the thick coriaceous character of



the calyx of both types of flowers and of the leaves. The leaves are very often triplinerved, and the upper surface sometimes has a rough scabrous texture, at least when dried. The venation, particularly the principal veins and primary vein branches, is very markedly raised; uncinata hairs on the venation are scattered or absent.

The range of this variety and of variety *parvifolia* nearly coincide except that variety *melastomaefolia* does not extend south of Kaneohe and variety *parvifolia* extends to Palikea and beyond. If this variety did arise by hybridization between variety *parvifolia* and variety *uncinata*, the mixing may have taken place in the Kaala region where, according to theory, a forest once existed between the two mountain ranges. The present distribution, then, would represent the distance to which the group has been distributed since its appearance. There are no real bases for such assumptions; further study, particularly of a cytological nature, may or may not uphold this hypothesis.



FIG. 3. Distribution of *Neraudia melastomaefolia* Gaud. var. *melastomaefolia* Cowan.

*Neraudia melastomaefolia* Gaud. variety *uncinata* Cowan, var. nov.

Fig. 4

**Diagnosis typi:** A var. *melastomaefolia* differt in foliis subtus pilis multis uncinatis in nervis secundariis, et in floribus sessilibus.

**Description of all material examined:** Shrub or small tree to 3 m. tall; upper branchlets

usually pendent, sparsely pilosulose. Petioles 1.0–5.5 cm. long, pilosulose, few to many appressed, ascending hairs present. Leaf blades 5–15 cm. long, 2–7 cm. wide, averaging 12 cm. long, 4.5 cm. wide, narrow-elliptic to elliptic, thin, usually palmate; upper surface sparsely pilosulose, hairs few, appressed, ascending on midrib, otherwise glabrous, lower surface hairs on principal veins and primary vein branches ascending, appressed, on other vein branches hairs shorter, erect or sub-erect, uncinata, largely restricted to venation; principal veins and primary branches raised; base cuneate or cuneate and decurrent, apex long-acuminate. Pistillate flowers sessile, calyx sparsely pilosulose, only few, appressed hairs present, beak attenuate apically with four acuminate teeth at apex; stigma 4–5 mm. long, one side not receptive. Achene 1.5–2.0 mm. long, averaging about 2 mm. long, apical portion depressed-conic, separated from basal portion by only slight constriction, basal portion convex, 2–3 mm. in diameter, outer margin plane, not involute; seed ovoid, without constriction. Staminate flowers sessile, acuminate tipped lobes 3.5–4.5 mm. long, 1.5–2.0 mm. wide, averaging 4 mm. long, 2 mm. wide, pilosulose with most hairs appressed, ascending but also with few shorter, sub-erect, uncinata hairs present; pistil rudiment 0.3–2.0 mm. long; filaments 2.5–5.5 mm. long, 0.5–1.0 mm. wide; anthers 1.5–2.0 mm. long, 0.8–1.0 mm. wide.

**Type:** Cowan 698, Oahu, Waikane–Schofield Trail, Kahana, Koolau Range, September 20, 1947. (Deposited in Bishop Museum [Ho].)

**Range:** Island of Oahu, Koolau Range, moist to wet forest, 1,800–2,200 feet altitude.

**Specimens examined**

**Data complete:** Kailauloa Mts., between Punaluu and Kaipapau, Nov. 14–21, 1908, *Forbes* (Ho); Punaluu, *Rock* 796, 368, 568, 626 (Ho); Punaluu Mt., trail to Castle Camp, *Rock* 8838 (Gr, Ho); Waikane–Schofield Trail, *St. John* 20251, 12120 (Ho), *Fosberg* 8774 (Ho), *Degener* 18185, 18185 (different sexes) (Ho), *Suehiro*, Oct. 16, 1932 (Ho), *Cowan* 56, 57,

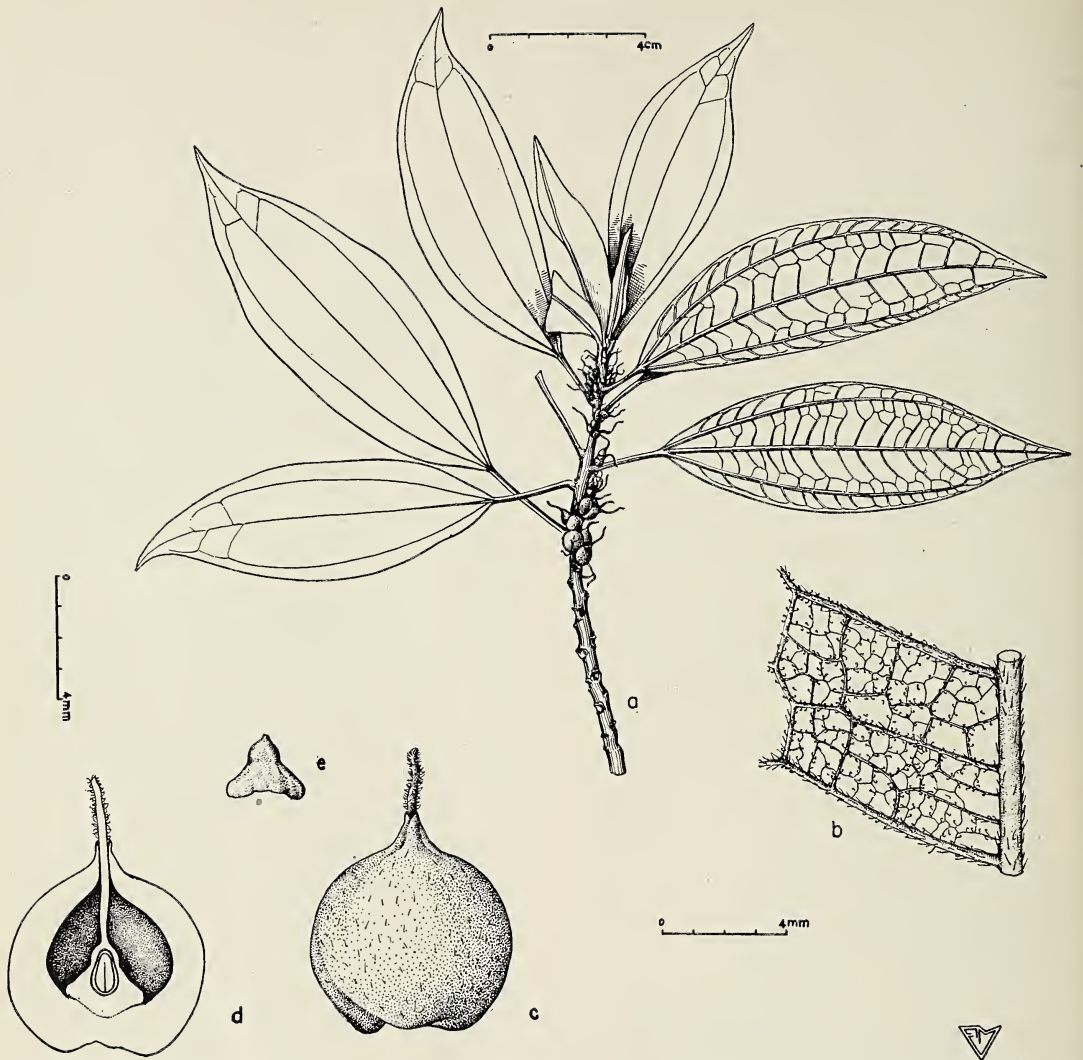


FIG. 4. *Neraudia melastomaefolia* Gaud. var. *uncinata* Cowan. *a-e*, Pistillate plant: *a*, habit (Type); *b*, portion of lower leaf surface (Type); *c*, mature calyx enclosing achene (Type); *d*, long section through mature calyx and achene (Type); *e*, external view of achene.

646, 697 (Ho), Cowan and St. John 7, 8 (Ho), Baxter 120 (Ho); Waiohole Valley, Rock, Dec. 1919 (Ho); east side of Kaala, Bergman (Ho).

The last collection cited above is the only one from the Waianae Range which may be placed in this variety but it is not certain that the locality data are correct. It is intermediate in some ways but it is closest to variety *uncinata* and so is placed here rather than in variety *melastomaefolia*, to which it shows some similarity.

Judging by Wawra's geographical note on his collection of *N. melastomaefolia*, he may have collected a plant of this variety. His locality is "Waiolani" which is in the Koolau Range, the home of variety *uncinata*, and would represent the most southerly occurrence of the group.

This variety may be recognized by the many short, sub-erect or erect uncinata hairs on the secondary and smaller vein branches on the lower leaf surfaces. (The name for this variety



is taken from this diagnostic character of the leaves.) The flowers are sessile, the leaves usually palmately veined, and both leaves and calyx lobes are thin compared to variety *melastomaefolia*.



FIG. 5. Distribution of *Neraudia melastomaefolia* Gaud. var. *uncinata* Cowan (half-black dots) and var. *parvifolia* Cowan (complete black dots).

*Neraudia melastomaefolia* Gaud. variety *pubescens* Cowan, var. nov.

Fig. 6

*Diagnosis typi:* A var. *melastomaefolia* differt in foliis subtus adpressi vel suberecti-pilosis, achenibus sine constrictione completa 3 mm. longis marginibus exterioribus involutis.

*Description of all material examined:* Tree to 6 m. tall with ascending branches, main stem to 13 cm. in diameter; upper branchlets pilosulose, hairs few to many, erect or sub-erect. Petioles 1.0–4.5 cm. long, averaging 2.5 cm. long, pilosulose, hairs few to many, appressed, sub-erect, or erect. Leaf blades 6.0–19.5 cm. long, 1.5–6.5 cm. wide, averaging 10 cm. long, 4 cm. wide, elliptic, thickish, palmate; above glabrous, below pilosulose, many appressed or sub-erect, ascending hairs present; margin entire, base cuneate and decurrent or slightly rounded and sub-obtuse, apex evenly or abruptly long-acuminate. Pistillate flowers sessile, calyx pilosulose, few to many ascending, appressed hairs present, beak attenuate apically with four acute teeth at apex; stigma 3–8 mm. long, one side often without receptive stigmatic hairs; calyx

surrounding mature achene thin, fleshy-coriaceous, 7.5–13.5 mm. long and 6–10 mm. wide, averaging about 10 mm. long and 8 mm. wide when fresh but drying to 5–8 mm. long, and 3.0–5.5 mm. wide, averaging 6 mm. long and 4 mm. wide. Achene 2.5–3.5 mm. long, averaging 3 mm., apical portion conic without complete, definite, constriction at base, basal portion occupying at least half of height of achene, 3–4 mm. in diameter at base, rounded, often deeply furrowed, outer margin strongly involute; seed ovoid with acute apex. Staminate flowers sessile or rarely pedicelled, calyx pilosulose, hairs many, ascending, appressed, and occasionally with few shorter uncinulate hairs, lobes navicular, 3.5–6 mm. long, 1.5–2 mm. wide, with acuminate or long-acuminate apex; pistil rudiment 0.8 mm. long; filaments 3.5–5 mm. long, 0.6–0.8 mm. wide; anthers 1.5–2 mm. long, 0.5–1 mm. wide.

*Type:* Heller 2792, Kauai, Kaholuamanu, above Waimea, Sept. 2–9, 1895. (Type deposited in Bishop Museum [Ho]; parts of type collection in P, G, UC, GH, NY, and Mich.)

*Range:* Island of Kauai, rain forest, 3,000–4,000 feet altitude.

*Specimens examined*

*Data complete:* Head of Awaawapuhi Valley, Honopu, *St. John et al.* 22890, 22891 (Ho); Waimea, forests of Kokee, *Skottsberg* 993 (Ho); Kokee-Nualolo Trail, *Selling* 3097 (Ho); Near Kokee Stream, *Degener* 18189 (NY); Halemanu, *Rock* 2374 (Ho) (2374–2386 [GH, Ho]); Kaholuamanu, *Rock* 9007 (Ho); Kaholuamanu, *Rock* 5327 (5326–5329) (Ho); Kaholuamanu, *Forbes* 398-K (Ho); Haupu, 2,000 feet, *MacDaniels* 887 (Ho); Waimea Drainage Basin, Kokee, West Side, *Forbes* 829-K (Ho); Waimea Drainage Basin, West Side, Kokee, side of Waimea Canyon, *Forbes* 865-K (Ho); Hii Mountains (Slopes of Puu Kahili, southwest of peak), *Forbes* 667-K (Ho).

*Data not complete:* Kauai, part of *Mann and Brigham* 624 (Ho).

The character separating this group from variety *uncinata*, which it closely approaches



FIG. 6. *Neraudia melastomaeifolia* Gaud. var. *pubescens* Cowan. a-f, Pistillate plant: a, habit (Type); b, portion of lower leaf surface (Forbes 829-K); c, young flower (Type); d, mature calyx enclosing achene (St. John et al. 22890); e, long section through mature calyx and achene (ibid.); f, external view of achene (ibid.). g-i, Staminate plant: g, habit (Rock 2379); h, young flower (ibid.); i, mature flower (ibid.).



in general appearance, is the lack of the many uncinata hairs on the venation of the lower leaf surface. It also differs from *uncinata* in that the hairs are evenly distributed over the entire lower leaf surface and are not restricted to the venation. (The varietal epithet for this entity is drawn from the pubescent condition of the lower leaf surface.) The basal portion of the achene of variety *pubescens* is also distinctive in that it is much raised, very broad, and involute at the outer margin. Also there is no complete constriction separating the apical and basal portions. The only plants of this group observed or on which there are available data were small trees 5 and 6 meters tall, erect, with stout ascending branches; plants of the other varieties of this species are normally weak, branching, or trailing shrubs of 3 meters or less in height.

The collections of this variety are quite uniform in aspect but there are a few minor exceptions which should be noted. The uncinata hairs so characteristic of variety *uncinata* are seldom seen in variety *pubescens* but in *Rock* (1916) and in his collection *Rock* 5328 there are many such hairs scattered indiscriminately over the lower leaf surface. The achene, however, is uniform in size and in the involute condition of the outer margin of the basal portion in all of the collections.

## KAUAI



FIG. 7. Distribution of *Neraudia melastomaefolia* Gaud. var. *pubescens* Cowan (half-black dots) and *Neraudia kauaiensis* var. *kauaiensis* (complete black dots).

*Neraudia melastomaefolia* Gaud. variety *parvifolia* (Wawra) Hbd., Fl. Haw. Is.: 416, 1888.

### Fig. 8

*Neraudia sericea* ? fm. *parvifolia* Wawra, Flora 57: 546, 1874.

*Neraudia melastomifolia* forma *truncata* Skottsberg, Horti Gotob., Acta 15(4): 351, 1944.

Low spreading shrub or half-vine 1–6 m. long; upper branchlets sparsely pilosulose, hairs few, ascending, appressed. Petioles 1–3 cm. long, pilosulose, hairs few, ascending, appressed. Leaf blades 3.0–8.5 cm. long, 1.5–5.0 cm. wide, averaging 6 cm. long, 3 cm. wide, lanceolate, elliptic-lanceolate, elliptic, elliptic-ovate, ovate, or oval, thin to sub-membranous, chartaceous, palmate; above sub-glabrous, with very few, straight, ascending, appressed hairs, below with few, straight, appressed hairs mostly restricted to veins; margin entire, base usually sub-obtuse or obtuse, sometimes slightly cordate or cuneate, apex usually abruptly acuminate or acute, only the principal veins slightly raised. Pistillate flowers on filiform pedicels 0.5–2.0 mm. long, calyx pilosulose with both straight, ascending, appressed hairs and shorter, erect, uncinata hairs, beak attenuate apically with four short, acute teeth at apex; stigma 3–5 mm. long, all sides receptive and stigmatic. Achene 1–2 mm. long, apical portion conic without constriction from basal portion (or rarely depressed-conic with constriction), basal portion flat, thin, outer margin plane, rarely revolute or involute, occasionally lobed, 2–3 mm. in diameter; seed ovoid. Staminate flowers with pedicels 0.5–2.0 mm. long, calyx with many, short, erect or sub-erect, uncinata hairs, longer, straight, appressed, ascending hairs sometimes present on margins of lobes of calyx or at extreme base, lobes 4–5 mm. long, 1.5–2.0 mm. wide, apex abruptly long-acuminate; filaments 3.0–4.5 mm. long, 0.5–1.0 mm. wide; anthers 2 mm. long, 1 mm. wide.

*Lectotype*: *St. John* 10599, Waianae Range, Puu Hapapa, Honouliuli, on ridge, 2,500 feet



FIG. 8. *Neraudia melastomaefolia* Gaud. var. *parvifolia* (Wawra) Hbd. a-g, Pistillate plant: a, habit (Lectotype); b, portion of lower leaf surface (*ibid.*); c, one node (*ibid.*); d, young flower (*ibid.*); e, mature calyx enclosing achene (Cowan and Sakimura 615); f, long section through mature calyx and achene (*ibid.*); g, external view of achene (*ibid.*). h-k, Staminate plant: h, habit (Cowan 673); i, young flower (Cowan and Sakimura 616); j, mature flower (*ibid.*); k, portion of one lobe of calyx (*ibid.*).



altitude, Oct. 19, 1930. (Type deposited in Bishop Museum [Ho].)

*Range:* Island of Oahu, Waianae Range, moist forest and moist pockets of forest along the ridges, 1,600–3,500 feet elevation, Mt. Kaala to Palikea.

*Specimens examined*

*Data complete:* Makaleha Ridge, *Rock* 17084 (Ho); Northeast slope of Puu Kumakalii, *Degener* 17506 (NY); First large side-valley south of Makua Valley, *Degener* 18183 (NY); Makaha Valley, *Forbes* (Ho); Puu Kaala, *Cowan and St. John* 325, 316 (Ho); Slope of Kaala, *Selling* 3669 (Ho); East ridge of Puu Kaala, *St. John* 9933 (Ho); Mt. Kaala, *Nitta* 37 (NY); Base of Kaala, northeast side, *Degener* 18191 (NY); Mt. Kaala Trail, *MacDaniels* 926 (Ho); Puu Hapapa, *St. John* 10422 (Ho); Small valley southeast of Puu Hapapa, *Degener* 18192 (NY); Small valley northeast of Puu Hapapa, *Degener* 18189 (Ho); Southeast slope of Puu Hapapa, *Degener* 12235 (Ho); South part of Puu Hapapa, *Selling* 3363 (Ho); Puu Hapapa, *Meebold* (Ho); Between Puu Kanehoa and Puu Kaua, *Degener* 17192, 17647 (NY); Middle ridge east of Puu Kanehoa, *Degener* 12803 (NY); Kanehoa, *Frederick* 206 (Ho); In gulch below Kanehoa, *Cowan* 1055, 1056 (Ho); Kupehau Gulch, *Cowan and St. John* 141, 147 (Ho); Along ridge trail in vicinity of Palikea, *Cowan and Sakimura* 615, 616, 617 (Ho), *Cowan* 663, 673, 690, 691, 803, 809 (Ho); Kaaikukae, *Russ* (Ho).

*Data not complete:* *Hillebrand*, no locality (K); Honolulu, *Hillebrand* (K); Oahu, *Forbes* (Ho); Oahu, *Remy* 198 (P).

Wawra in 1874 described a forma *parvifolia* of *N. sericea* which *Hillebrand* raised to varietal status and transferred to *N. melastomaefolia*. The range given by *Hillebrand* fits very well and the description is adequate for recognition. However, the size of the leaves and petioles described by Wawra and copied by *Hillebrand* suggests that Wawra probably had an unusually small-leaved form. G. von Beck, in a consideration of Wawra's work, transferred Wawra's

collection (151), originally cited under his forma *parvifolia* of *N. sericea*, to *N. melastomaefolia* but did not consider it to be any different from the "typische Form." In entirety, he says, "Alpine Form mit kleinen Blättern (4 cm. lang), sonst wie die typische Form." In 1935 *St. John* made a search in the herbarium at Vienna for this material but neither he nor the director was able to locate it. In spite of this, *Hillebrand's* interpretation of this group is accepted and the name applied.

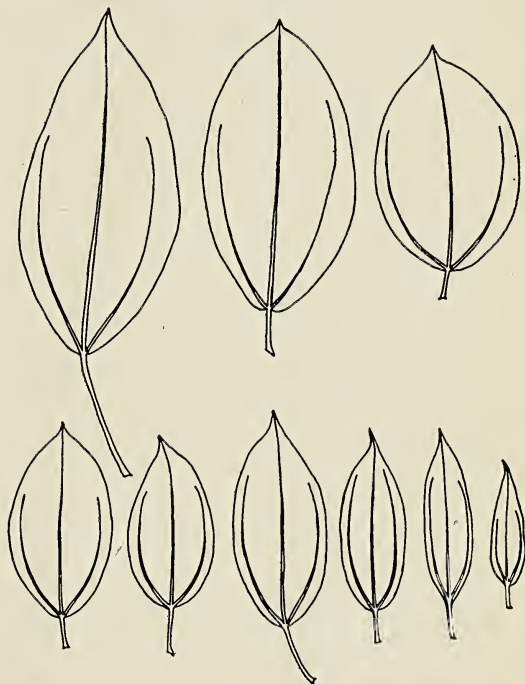


FIG. 9. Outlines of leaves to show variation in leaf shape and size in *Neraudia melastomaefolia* Gaud. var. *parvifolia* (Wawra) Hbd.

Upon first examination of the facts it seemed that *Meyen's* name, *N. glabra*, should be applied to this group but additional and more detailed study has revealed that *Meyen's* name is not applicable in this genus. In his journal, writing of his excursion into Nuuanu Valley, he says (translated), "Here we found the plant called 'mamaku' from which the Indians make their ordinary tapa; it belongs to the Urticaceae and is *Neraudia melastomaefolia* Gaud.; a new species of this genus, *Neraudia glabra* n. sp.,

grows here very plentifully and is likewise used in making the cloth." Then in a footnote he described his new species as follows: "N. foliis late ovatis acuminatis crenatis utrique glabris!" Later, in 1843, in Walpers Enumeration of the family he transferred his own species to *Boehmeria* with a slightly different description: "Foliis (oppositis an alternis?) late ovatis acuminatis crenatis utrinque glaberrimis penninerviis." It seems from the data above that Meyen had a specimen of another genus rather similar in aspect to *Neraudia*, perhaps *Pipturus*. The Hawaiian name "mamake" is recorded by most workers for *Pipturus* and is basically the "mamaku" of Meyen. The crenate margin of the leaves is a definite characteristic of the species of *Pipturus* and the penninerved condition of the leaves which Meyen describes does not fit *Neraudia* at all. Also this group, variety *parvifolia*, occurs only in the Waianae Range. It seems obvious that Meyen's name is based upon something other than *Neraudia* and it is excluded although his material is now impossible to obtain for verification. The director of the herbarium at Vienna has notified us that the section of the herbarium containing the Urticaceae was destroyed by fire during the recent war. This same catastrophe also destroyed Wawra's material.

This group has been the most commonly collected of the genus but it is quite local in its occurrence. It is separated from variety *melastomaefolia* and variety *uncinata* by the almost completely glabrous condition of the lower leaf surface, by the usually sharply conic achene, by the predominance of short, erect, uncinat hairs on the staminate flower calices, by the typically obtuse or sub-obtuse leaf bases, and by the thin to sub-membranous leaves. It has, in common with variety *melastomaefolia*, pedicelled flowers, but it may be separated (even in the sterile condition) by the thinner leaves, the often obtuse or sub-obtuse base, and by the only slightly raised venation. The greatest difficulty in this group is that of getting actively flowering material and the result is that unless the material

is in good flowering or fruiting condition it is difficult to identify with the keys. This is true because the pedicels which characterize the group are present only in a fertile or recently fertile state; Key II should assist in the identification of such collections as are in the vegetative state, without flowers, or only weakly flowering. (See Fig. 5 for distribution.)

*Neraudia melastomaefolia* Gaud. variety *Gaudichaudii* Cowan, *var. nov.*

*Diagnosis typi:* A var. *melastomaefolia* differt in foliis subtus adpressi-pilosulis, lobis calycum masculorum sine pilis uncinatis.

*Description of all material examined:* Shrub; upper branchlets curving, pendent, sparsely appressed pilosulose. Petioles 1-4 cm. long, sparsely pilosulose. Leaf blades 6.5-14.0 cm. long, 3.5-6.0 cm. wide, averaging 9 cm. long, 4 cm. wide, elliptic, thin to thickish, usually triplinerved; above glabrous or with very few appressed hairs, below pilosulose with many long, straight, appressed or sub-erect hairs (0.8-1.0 mm. long) scattered over entire surface; principal veins raised, primary branches less salient; base cuneate and usually markedly decurrent, apex abruptly acuminate with usually a blunt tip. Pistillate flowers sessile, calyx pilosulose with many appressed, ascending hairs, beak attenuate apically with four acuminate teeth at apex; stigma 2-5 mm. long, one side lacking receptive stigmatic hairs. Achene 1.75-2.0 mm. long, apical portion depressed conic, separated from basal portion by only slight constriction, basal portion thickened, flattened, 2.0-2.5 mm. in diameter, outer margin plane. Staminate flowers on short pedicels 0.5-1.0 mm. long, calyx pilosulose with many straight, appressed, ascending hairs, lobes navicular, 3-4 mm. long, 1.0-1.5 mm. wide; filaments 3.5-4.0 mm. long, 0.4-0.5 mm. wide; anther sacs 1.5-2.0 mm. long, 0.75-1.0 mm. wide.

*Type:* *Selling* 3697, Oahu: Koolau Mts., Punahoa. September 27, 1938. (Type deposited in Bishop Museum [Ho].)



*Range:* Oahu, Punaluu region of Koolau Range in upper rain forest.

*Specimens examined:* Pig-God Trail, Punaluu, *Degener* 18184 (NY), 17117 (NY); Punaluu, *Webster* 1603 (U. of Tex.).

This variety is similar in appearance to variety *uncinata* but differs in its complete lack of uncinata hairs on any plant part, by its staminate flowers borne on pedicels, and by the presence of many rather long hairs scattered over the entire lower leaf surface. In this latter character it resembles variety *pubescens* but differs in its smaller calices, by the depressed-conic apical portion of the achene, and by its usually triplinerved leaves. It is remarkably similar to variety *melastomaefolia* but the long hairs all over the lower leaf surface and the lack of uncinata hairs on any plant part separate it from this variety. Variety *Gaudichaudii* appears to be most closely related to variety *melastomaefolia*.

This variety is named in honor of Charles Gaudichaud, one of the most illustrious botanical travelers of the early exploratory period of the Hawaiian Islands. He described many genera from these islands and the genus *Neraudia* was one of them. He is also the author of three of the species assigned to the genus.

*Neraudia melastomaefolia* Gaud. variety *pallida* Cowan, *var. nov.*

*Diagnosis typi:* A var. *melastomaefolia* differt in foliis subtus glabris, pallidissimis, floribus sessilibus, rostro calycis ad apicem plerumque expanso.

*Description of all material examined:* Upper branchlets sub-glabrous with few, straight, ascending, appressed hairs. Petioles 1–3 cm. long, glabrous or sparsely pilosulose with few, ascending, appressed hairs. Leaf blades 6.0–7.5 cm. long, 1.5–3.0 cm. wide, elliptic, oblance-elliptic, or somewhat obovate, thin, palmate; upper surface with very few, ascending, appressed hairs, under surface glabrous or with few hairs on venation; margin entire, base narrowing, cuneate or sub-obtuse, apex abruptly or evenly acuminate or long-acuminate. Pistillate flowers

sessile, calyx with few ascending, appressed hairs, beak expanding apically or sometimes attenuate, four-toothed; stigma 4–7 mm. long and receptive on all surfaces or stigmatic hairs sometimes absent from one side. Achene (mature ?) about 1 mm. long, apical portion hemispherical or elongate-hemispherical without constriction from basal portion, outer margin of basal portion plane, about 2 mm. in diameter; seed ellipsoid. No staminate flowers available.

*Type:* *Forbes* 2365-M, ridge upper part of Olowalu Valley, Maui, May 14, 1920. (Type deposited in Bishop Museum [Ho].)

*Range:* Island of Maui, western part.

*Specimen examined:* *Forbes* 2470-M, up Olowalu Valley and up right-hand side on ridge, May 23, 1920 (Ho).

The material representing this group is so scanty that its evaluation and proper position in relation to other groups are not entirely clear. The group is recognizable and therefore is named in order to call it to the attention of future collectors. It may be separated by the very pallid appearance of the lower leaf surface when dry and the usually expanded beak of the pistillate calyx. (See Fig. 20 for distribution.)

*Neraudia angulata* Cowan, *sp. nov.*

*Diagnosis:* Frutex, 1.5–3.0 m. altus; petiolis 0.8–3.0 cm. longis, perbreviter pilosis, laminibus 6.5–13.0 cm. longis, 3.5–5.0 cm. latis, ellipticis vel elliptico-ovatis vel ovatis tenuibus supra adpressi-pilosulosis infra valde curvati-vel adpressi-pilosulosis sericeis marginibus integris vel partim dentatis vel dentatis ad basim cuneatis vel sub-obtusis vel obtusis ad apicem gradatim vel abrupte longi-acuminatis aliquando triplinervatis. Floribus femineis sessilibus, calycibus angulatis valde adpressi-pilosulosis et erecti-pilosulosis, rostro calycis ad apicem contracto acute 4-dentato, stigmatibus 2–8 mm. longo uno latere sine pilis receptivis. Achaenis 1.5–2.0 mm. longis, parte apiculo conico ad basim sine constrictione, parte basali crasso 1.5–2.0 mm. diametro marginibus exterioribus in sicco nonnihil involutis et angulatis,

in calyce carnosio 0.75–1.25 mm. crasso subalato angulatoque inclusis; semene ovato. Floribus masculis sessilibus vel rare pedicellatis, calycibus valde pilosulosis, lobis 2.0–3.5 mm. longis 1.0–1.5 mm. latis anguste navicularibus ad apicem longi-acuminatis, filamentis 4 mm. longis, 0.75 mm. latis, anteris reniformibus 1.5 mm. longis 0.75 mm. latis.

*Description of all material examined:* Erect shrub 1.5–3.0 m. tall, 1–4 cm. in diameter at base of main stem, upper branchlets with many erect and appressed, or only erect, hairs. Petioles 0.8–3.0 cm. long, with many appressed and erect hairs. Leaf blades 6.5–13.0 cm. long, 3.0–5.5 cm. wide, elliptic-ovate, ovate, or oval, thin, palmate or triplinerved; above sparsely sericeous, hairs ascending, below sericeous with more or less dense layer of strictly appressed or sub-erect hairs, oriented centripetally within primary intervals and mostly directed toward margin, pilosulose on raised principal veins, hairs appressed or sub-appressed; margin entire, repand, partly dentate or completely dentate, base cuneate-decurrent to obtuse and rotund, apex evenly or abruptly long-acuminate or only acute. Pistillate flowers sessile, calyx sericeous, hairs appressed to erect intermixed with some shorter, erect, uncinat hairs, calyx beak attenuate apically with four sub-acuminate to long-acuminate teeth at apex; stigma 2–8 mm. long, without receptive stigmatic hairs on one surface. Achene 1.5–2.0 mm. long, angled, apical portion conic, not separated from basal portion by constriction, basal portion flat-convex, 1.5–3.0 mm. in diameter, outer margin drying involute; seed ovoid. Staminate flowers sessile or with pedicels 1 mm. or less long, calyx sericeous, hairs ascending, lobes navicular, 2.0–3.5 mm. long, 1.0–1.75 mm. wide, apex long-acuminate; filaments 3–4 mm. long, 0.3–0.5 mm. wide; anther sacs 1.5–2.0 mm. long, 0.5–1.0 mm. wide.

This species is separated from all others by the sericeous condition of the plants, particularly of the lower leaf surface and by the conspicuously angled and ridged, fleshy calyx surround-

ing the mature achene. The two varieties comprising the species are separated on the basis of the posture of the hair on the lower leaf surface and on the leaf margin. The name for the species is taken from the angled character of the mature pistillate calyx.

This is the group to which Hillebrand applied Gaudichaud's name, *Neraudia sericea*, when he reduced it to a variety of *N. melastomaefolia*. A fragment of Hillebrand's material, which upon examination proves to be what is named here *N. angulata*, is in the herbarium of Bishop Museum.



FIG. 10. Leaf outlines to show variation in leaf shape and shape of leaf base in *Neraudia angulata* Cowan var. *angulata* Cowan.

*Neraudia angulata* Cowan variety *angulata* Cowan, var. nov.

*Diagnosis typi:* A var. *dentata* differt in foliis marginibus semper integris subtus valde adpressi-pilosulosis sericeis.

*Description of all material examined:* Shrub 2.0–2.5 m. tall. Petioles 1–5 cm. long. Leaf blades 7–13 cm. long, 3.5–5.0 cm. wide, averaging 8 cm. long, 4 cm. wide, elliptic or elliptic-ovate, margin entire, base cuneate-decurrent, apex long-acuminate; below sericeous with more or less dense covering of appressed hairs, centripetally oriented in primary intervals and somewhat marginally directed, producing a conspicuous geometrically uneven sheen on lower leaf surface.



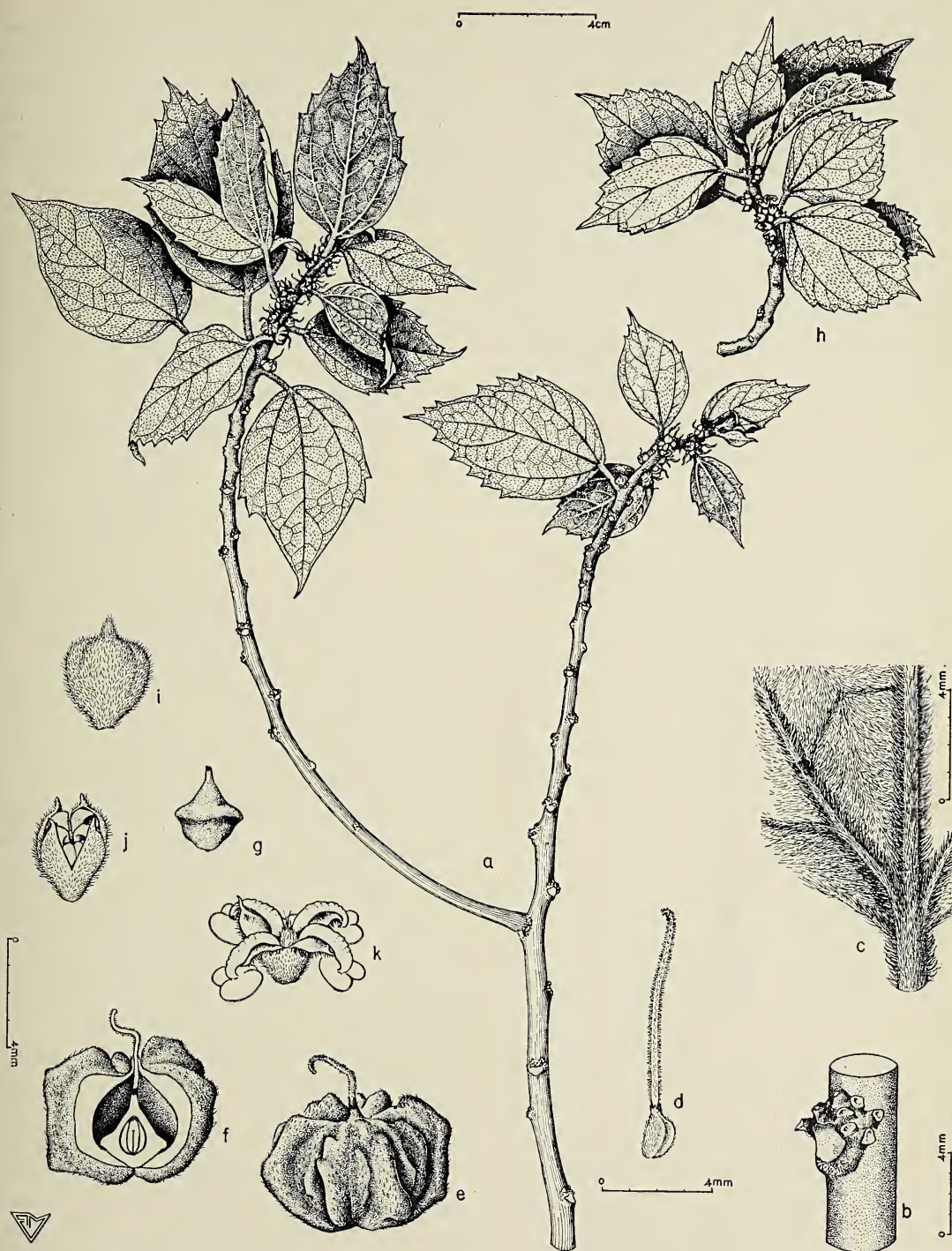


FIG. 11. *Neraudia angulata* Cowan var. *dentata* Degener and Cowan. *a-g*, Pistillate plant: *a*, habit (Type); *b*, one node (Type); *c*, portion of lower leaf surface (Type); *d*, young flower (Type); *e*, mature calyx enclosing achene (Type); *f*, long section through mature calyx and achene (Type); *g*, external view of achene (Type). *b-k*, Staminate plant: *h*, habit (Cowan 761); *i*, young flower (*ibid.*); *j*, opening flower (*ibid.*); *k*, mature flower (*ibid.*).

*Type:* Forbes 1828-O, Mokuleia, slopes of Kaala, April 26–May 16, 1912. (Type deposited in Bishop Museum [Ho].)

*Range:* Island of Oahu, Waianae Range, in dry situations 1,900–2,500 feet altitude.

*Specimens examined*

*Data complete:* West face of Puu Kalena, Waianae Kai, Fosberg 9264 (Ho); West branch of Waianae Valley at pali near Kolekole Pass, Degener 18182 (NY); Puu Kaua, on easterly ridge, Cowan 840 (Ho).

*Data not complete:* Honolulu, Hillebrand (K); Hillebrand, no locality (K); Remy 196, Hawaii (almost certainly incorrect locality) (P).

This typical variety may be distinguished from *dentata* by the entire leaf margin and the strictly or mostly appressed hair on the lower leaf surface. Rarely, *dentata* has an entire margin and then it is only the posture of the pubescence which must serve to identify it.

*Neraudia angulata* Cowan variety *dentata* Degener and Cowan, *var. nov.*

Fig. 11

*Diagnosis typi:* A var. *angulata* differt in foliis marginibus dentatis subtus valde curvati-pilosulosis sericeis.



FIG. 12. Leaf outlines to show variation in dentation of leaves in *Neraudia angulata* Cowan var. *dentata* Degener and Cowan.

*Description of all material examined:* Shrub 1–3 m. tall. Petioles 0.8–3.0 cm. long; leaf blades elliptic, elliptic-ovate, or ovate, margin dentate, partly dentate, repand, or rarely entire, base cuneate-decurrent to obtuse, apex abruptly or evenly long-acuminate or only acute; below densely sericeous, hairs sub-erect or erect, geometrically uneven sheen on lower leaf surface

not so conspicuous as in preceding, owing to more nearly erect hairs, most hairs curving toward margin apically.

*Type:* Cowan 750, Extension of fire-break trail, west of Puu Iki, Waianae Range, Oahu, December 7, 1947. (Type deposited in Bishop Museum [Ho].)



FIG. 13. Distribution of *Neraudia angulata* Cowan var. *angulata* Cowan (half-black dots) and var. *dentata* Degener and Cowan (complete black dots).

*Range:* Island of Oahu, Waianae Range, dry areas, 1,200–2,100 feet altitude.

*Specimens examined*

*Data complete:* Kaena Uplands, MacCaughy (Ho); Kamananui, second valley east of Puu Iki, Russ (Ho); Extension of fire-break trail, west of Puu Iki, above Mokuleia, Cowan, Webster, and Wilbur 751–763 (Ho), Degener 19181 (NY); Lualualei, central section below Kanehoa, foot of cliffs, head of valley 3, Christophersen 3682, 3685, 3686 (Ho); Lateral easterly ridge, ¼ mile north of Puu Kaua, Cowan 836, 837, 839, 849 (Ho).

The extent of dentation of the leaves of this variety varies considerably but usually leaves with some teeth can be found on each plant. When a collection is discovered with no dentation it is necessary to observe the posture of the pubescence on the lower leaf surface. In this variety the pubescence is sub-erect or erect and the upper part of each hair is usually curved toward the margin.

Otto Degener recently collected some material of this variety and pointed out its dis-



tinctness to me. He then kindly directed me to his locality where fourteen collections were made of plants of both sexes. Although the group had been recognized previously, the material available for its study was quite inadequate so that Mr. Degener's assistance was a very definite contribution and is gratefully acknowledged.

*Neraudia kauaiensis* (Hbd.) Cowan, *comb. nov.*

*Neraudia melastomaefolia* Gaud. var. *Kauaiensis* Hbd., Fl. Haw. Is.: 416, 1888.

Upper branchlets grayish at tip with very many straight, erect, or sub-erect hairs. Petioles 1–7 cm. long, with very many straight, erect hairs. Leaf blades 6–12 cm. long, 3.5–7.0 cm. wide, elliptic, elliptic-ovate or broadly ovate, thin, palmate, above with few to many sub-appressed to erect hairs, tuft of hairs at junction of principal veins on upper surface erect, below with very many, more or less erect, irregularly curving and bending or almost straight hairs in intervals; veins densely covered with straight, erect hairs; margin entire or irregularly undulate, base rotund or narrowing, sub-cordate, obtuse, or sub-obtuse, apex abruptly acuminate or long-acuminate. Pistillate flowers sessile, calyx densely pilosulose, hairs many, erect or sub-erect, ascending, beak attenuate apically with four short, acute or acuminate teeth at apex; stigma about 6 mm. long, receptive on all surfaces. Achene about 2 mm. long, apical portion conic, no constriction between apical and basal portions, basal portion flattened, thin, about 2 mm. in diameter, outer margin plane. Staminate flowers sessile, short-pedicelled, or with pedicels up to 2.5 mm. long, calyx with many sub-erect, ascending hairs, lobes navicular, 3–4 mm. long, 1–2 mm. wide, with long-acuminate apex; pistil rudiment less than 1 mm. long, filaments flat, strap-shaped, 2.8–4.5 mm. long, 0.2–0.5 mm. wide; anther sacs reniform, 0.8–2.0 mm. long, 0.4–1.0 mm. wide.

This species is easily separable from all other groups in the genus, except *N. sericea*, on the

basis of the pubescence of the lower leaf surface. The leaves of *N. kauaiensis* usually have a sub-cordate base (except in variety *Helleri* which has irregularly undulate leaf margins) as compared to the usual cuneate base of *N. sericea*. The pubescence on the calices of flowers of both sexes in *N. sericea* is appressed, ascending, whereas the pubescence on the calices in *N. kauaiensis* is erect or sub-erect, ascending. The venation of the leaves of the two groups is different and the achene of *N. sericea* has a deep, usually acute constriction whereas the achene of *N. kauaiensis* has no such constriction.

*Neraudia kauaiensis* (Hbd.) Cowan variety *kauaiensis* Cowan, *var. nov.*

Fig. 14

*Description of all material examined:* Petioles 1–6 cm. long, averaging 2 cm. long. Leaf blades 6–11 cm. long, 3.5–7.0 cm. wide, averaging 7 cm. long, 4.5 cm. wide, elliptic-ovate or more often broadly ovate; above sparsely pilosulose, few to many sub-appressed to erect hairs present; margin entire, base rotund, sub-cordate or obtuse. Pistillate flowers sessile. Achenes as in specific description. Staminate flowers sessile or short-pedicelled, calyx lobes 4 mm. long, 1 mm. wide with acuminate apex; filaments 2.8–4.5 mm. long, 0.2–0.5 mm. wide; anther sacs 0.8–2.0 mm. long, 0.4–0.7 mm. wide.

*Type:* Rock 5323 (Ho) (5322–5331 [Ho, GH]), Kaholuamanu, Kauai. (Type deposited in Bishop Museum [Ho]; portions of this collection series in GH.)

*Range:* Island of Kauai, wet forests.

*Specimens examined*

*Data complete:* On Kaholuamanu, above Waimea, *Heller* 2881 (UC, Ho, G, P, NY, Mich.); Kaholuamanu, *Rock* 17111 (Ho); Waimea Drainage Basin, West Side (Kokee region—from Forbes' field book), *Forbes* 1079-K (Ho); Kalalau Valley, *Forbes* 52-K (Ho).

*Data not complete:* *Rock* 5922 (Ho); *Mann and Brigham* 624 (in part—due to the group-



FIG. 14. *Neraudia kauaiensis* (Hbd.) Cowan var. *kauaiensis* Cowan (a-e); var. *Helleri* (i). a-e, Pistillate plant: a, habit (Type); b, portion of lower leaf surface (Type); c, young flower (Type); d, external view of achene (Type); e, long section through achene (Type). f-h, Staminate plant: f, habit (Rock 5331); g, young flower (*ibid.*); h, mature flower (Heller 2881). i, Outline of leaf of var. *Helleri* (Type).



ing of several collections under one number) (GH, G).

This typical variety differs from variety *Helleri* principally in its entire leaf margins. The different leaf shape and the long-pedicelled staminate flowers of variety *Helleri* serve to separate the two varieties.

*Neraudia kauaiensis* (Hbd.) Cowan variety *Helleri* Cowan, *var. nov.*

*Diagnosis typi:* A *var. kauaiensi* differt in marginibus foliorum undulatis, petiolis longioribus, pedicellis longioribus.

*Description of all material examined:* Petioles 3–7 cm. long, averaging 5 cm. long. Leaf blades 6.5–12.0 cm. long, 3.5–5.5 cm. wide, averaging 8 cm. long, 4 cm. wide, elliptic to elliptic-ovate; above with many very short, appressed or sub-erect hairs; margin irregularly undulate, base obtuse or sub-obtuse. Pistillate flowers unknown. Staminate flowers with pedicels 0.5–2.5 mm. long, averaging 2 mm. long, calyx lobes 3.0–3.5 mm. long, 1.5–2.0 mm. wide; filaments 3–4 mm. long, 0.5 mm. wide; anthers 1.5–2.0 mm. long, 0.8–1.0 mm. wide.

*Type:* Heller 2847 (NY), "On Kaholuamanoa, above Waimea, October 1–8, 1895," Kauai (NY, P, GH, G). (Type deposited at New York Botanical Garden; also sheets at P, GH, and G.)

*Range:* Known from the type locality only.

*Specimens examined:* Only type collection available for study.

Although the material for this group is inadequate, it seems to be a distinct entity to which a name should be applied. It may be distinguished from variety *kauaiensis* by its irregularly undulate leaves and the presence of many long filiform pedicels at each node. No pistillate material is available but it is hoped that future collections in this locality may reveal the nature of the pistillate plants.

The name for this group was chosen in recognition of the outstanding field work accomplished by A. A. Heller in the Hawaiian Islands in 1895. His very acute powers of observation

and awareness of plant differences resulted in the description of many new species and in a collection of much valuable material.

*Neraudia ovata* Gaud., Freyc. Voy. Uranie Bot.: 501, 1830.

Fig. 15

*Neraudia pyrifolia* Gaud., Freyc. Voy. Uranie Bot.: 94, 1826 (nomen nudum).

*Boehmeria ovata* (Gaud.) Endl., Wien Mus. Naturgesch., Ann. 1: 165, 1837.

*Boehmeria ovata* (Gaud.) Steudel, Nom. Bot. 2: 192, 1841.

*Neraudia melastomaefolia* Gaud. *var.-β* Wedd., Mus. Hist. Nat. Paris, Nouv. Arch. 9: 438–439, 1856–57.

*Description of Gaudichaud's material:* Upper branchlets with many short, straight, erect hairs. Petioles 1–2 cm. long. Leaves 5–6 cm. long, 3–4 cm. wide, ovate or oval, thin, palmate; above with few, very short, ascending, appressed hairs, below puberulent with many very fine, more or less erect, very short, straight or slightly bending hairs; margin entire, base obtuse or cuneate, apex contracted abruptly into an acuminate or long-acuminate tip. Pistillate flowers sessile, calyx pilosulose, hairs many, short, ascending, appressed, and with few erect, uncinuate hairs intermixed, beak expanded or attenuate apically. Achene about 2 mm. long, apical portion depressed-conic, separated from basal portion by obtuse constriction, basal portion raised, involute at outer margin, about 2.5 mm. in diameter. No staminate flowers available.

*Description of all material examined:* Vining, sprawling, rarely erect shrub 1–3 m. tall with a spread of 3–7 m., sometimes clambering over adjacent vegetation, main stem up to 5 cm. in diameter at base; upper branchlets pilosulose, with many short, erect hairs. Leaf blades 3–10 cm. long, 2–6.5 cm. wide, elliptic, elliptic-ovate, ovate, broadly ovate, or oval, thin, palmate; above sparsely puberulent, below more densely puberulent; margin entire, base usually obtuse or sub-obtuse, sometimes cuneate, apex abruptly or evenly acuminate or long-acuminate, occasion-



FIG. 15. *Neraudia ovata* Gaud. *a-g*, Pistillate plant: *a*, habit (Type); *b*, one node (Type); *c*, portion of lower leaf surface (Cowan et al. 481); *d*, young flower (*ibid.*); *e*, mature calyx enclosing achene (*ibid.*); *f*, long section through mature calyx and achene (*ibid.*); *g*, external view of achene (*ibid.*). *b-j*, Staminate plant: *b*, habit (Cowan et al. 477); *i*, young flower (Cowan et al. 486); *j*, mature flower (*ibid.*).



ally only acute. Pistillate flowers sessile, calyx pilosulose, with dense covering of appressed to sub-erect hairs and shorter, erect, uncinuate hairs, beak expanded or attenuate apically, four-toothed or three-toothed and collar-form; stigma 4–7 mm. long, receptive on all surfaces. Achene 2–3 mm. long, apical portion depressed conic, separated from basal portion by complete, obtuse, or acute constriction, basal portion raised and sometimes somewhat lobed, about 3 mm. in diameter, outer margin involute; seed ovoid with lateral, transverse constriction. Staminate flowers sessile or on pedicels 1 mm. or less in length, calyx pilosulose with dense covering of appressed and erect hairs, with shorter, erect, uncinuate hairs intermixed, lobes membranous, with long-acuminate apex, 3.0–4.5 mm. long, 1.0–1.5 mm. wide; pistil rudiment 0.3–1.0 mm. long, filaments 3–5 mm. long, 0.5–0.75 mm. wide, anther sacs 1–2 mm. long, 0.5–1.0 mm. wide.

*Type:* Gaudichaud, "In insulis Sandwicensibus." (Type deposited in Museum National d'Histoire Naturelle de Paris [P].)

*Range:* Island of Hawaii, dry parts of lava fields 1,000–3,000 feet altitude.

*Specimens examined*

*Data complete:* Peter Lee Road near Half-Way House, *Fagerlund and Mitchell* 842 (Ho); Kau, *Rock* 8776 (Ho, GH); Kapua, *MacDaniels* (Ho); Kanahaha, Kona, *Forbes* 361-H (Ho); Puuwaawaa, *Forbes* 28-H (Ho); North Kona, below Lind's Place and Puuwaawaa branch road, *Skottsberg* 1956 (Ho); Puuwaawaa, *Degener* 18187 (NY); North Kona, Puuwaawaa, *Skottsberg* 673 (Ho); Puuwaawaa,  $\frac{3}{4}$  mile west of Puu Anahulu, *Cowan* 483–486 (Ho); Puuwaawaa, North Kona, *Fagerlund and Mitchell* 1019 (Ho); Huehue, North Kona, *Rock* 4015 (Ho) (4013–4017 [GH, Ho]); North Kona, vicinity of Huehue near main road, *Selling* 3203 (Ho); Huehue, North Kona, *Frederick* (Ho); North Kona, near Lind's Place, *Skottsberg* 1962 (Ho); Huehue, *Meebold* (Ho); Near Huehue Ranch, Kaupulehu, *Cowan et al.* 477–482 (Ho).

The leaf shape in this species is variable and though it is not always ovate as Gaudichaud supposed, there is a tendency in that direction. The material on which Gaudichaud based his description shows leaves which are predominantly broadly ovate but the many later collections show the inconstancy of this character. In several of the collections a few or all the leaves are elliptic but the extreme of this condition is reached in *Cowan et al.* 485 in which the leaves are narrow elliptic with a long-acuminate apex and cuneate base and the petioles average longer than in the remainder of the material. A group of some status might be segregated on these differences but I have not been convinced of the justification of such a segregation.

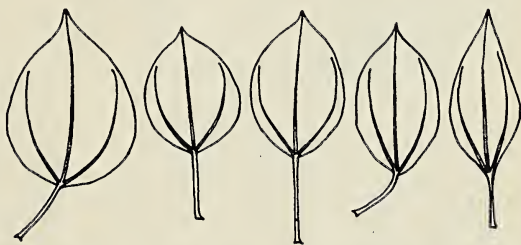


FIG. 16. Leaf outlines to show variation in leaf shape in *Neraudia ovata* Gaud.

The shape and size of the achene are generally constant, at least in the involution of the outer margin of the basal portion. However, in *Forbes* 28-H and 361-H the outer margin is thin and plane instead of strongly involute as is typical.

This species is unlike any other group in the genus in its vining or clambering habit. From limited observations, it seems that the plants remain more or less erect shrubs with lax, arcuate, branches until of considerable size. That the vine-like habit is characteristic is indicated by several very large (up to 7 m. long) plants which were observed to be clambering over and into adjacent *Metrosideros* trees. Ten collections of the group were made on Hawaii during December, 1946. The plants were found growing in dry soil or out of

crevices between boulders of rough lava. Several seedlings were collected from beneath one pistillate plant and one of these was successfully grown for 18 months in the cool, humid conditions of Manoa Valley on Oahu. This fact would seem to indicate that the plant is capable of considerable adjustment, for the conditions under which it grew on Oahu are nearly the opposite of those in the original locality. The puberulent character of the leaves and their shape remained typical after a year and a half of cultivation. It flowered twice, producing pistillate flowers. Pollination with pollen from an Oahu plant (of another species) was attempted without success. This observation may indicate that genetic barriers exist between some of the groups.

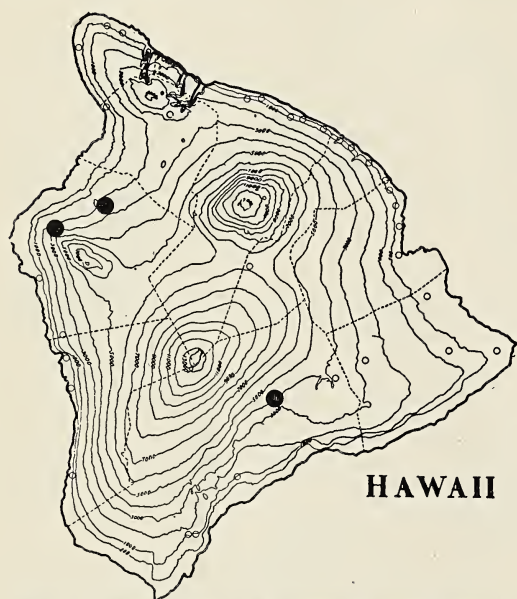


FIG. 17. Distribution of *Nerandia ovata* Gaud.

*Nerandia sericea* Gaud., Bot. Voy. Bonite: pl. 133, 1851.

Fig. 18

*Description of Gaudichaud's material:* Upper branchlets pilosulose, hairs many, erect, or sub-erect, ascending. Petioles 1–3 cm. long, pilosulose, hairs many, irregularly bending. Leaf blades 7.0–9.5 cm. long, 4.0–6.5 cm. wide, broadly oval or ovate, rather thickish, tripli-

nerved or palmate; above with few ascending, appressed hairs and tuft of hair at point of divergence of principal veins also appressed, ascending, below densely pilosulose, hairs irregularly bending and curving, grayish or whitish, rather shiny, 0.8 mm. or more long; on upper surface of venation hairs ascending, appressed, on lateral surfaces hairs divergent; margin entire, base cuneate or sub-obtuse, apex contracted abruptly or tapering evenly into an acute to long-acuminate tip, principal veins raised on lower leaf surface. Pistillate flowers sessile, calyx pilosulose with many straight, ascending, appressed hairs; stigma with one side lacking stigmatic hairs. No mature achenes or staminate flowers available.

*Description of all material examined:* Upper branchlets with very many short, erect or sub-erect hairs. Petioles 0.8–5.0 cm. long, averaging 3 cm. long, with many erect to sub-erect hairs. Leaf blades 3.5–8.5 cm. long, 2–5 cm. wide, averaging 7 cm. long, 4 cm. wide, thin to thickish, narrowly elliptic, elliptic-ovate, ovate, slightly obovate, oval, or broadly oval, mostly triplinerved; above pilosulose with many ascending, appressed hairs, tuft of hairs at junction of principal veins on upper surface appressed, ascending, below densely pilosulose, hairs irregularly bending and curving, grayish or whitish, pilosulose on principal veins and primary branches, hairs appressed, ascending, lateral surfaces of veins with or without fringe of hairs oriented at approximately 90° to the veins; margin entire or rarely a few teeth present on very young leaves, base cuneate, rarely sub-obtuse or obtuse, apex abruptly or sometimes evenly long-acuminate, acuminate, or acute. Pistillate flowers sessile, calyx pilosulose with many straight, appressed, ascending hairs and few shorter, erect, uncinat hairs, beak expanded apically or rarely attenuated to four-toothed, entire, or laciniate apex; stigma 3–5 mm. long, all sides receptive. Achene 1.5–2.0 mm. long, apical portion depressed-conic, separated from basal portion by deep, acute or obtuse constriction, basal portion flat-convex, 2.5–3.0 mm.





FIG. 18. *Neraudia sericea* Gaud. a-e, Pistillate plant: a, habit (Rock); b, portion of lower leaf surface (Rock); c, young flower (Type); d, external view of achene (Rock); e, long section through achene (Rock). f-h, Staminate plant: f, habit (Forbes 2324-M); g, young flower (*ibid.*); h, mature flower (*ibid.*).

in diameter, outer margin plane; seed ovoid with constriction in upper part. Staminate flowers sessile or with pedicels 1–2 mm. long, calyx pilosulose with many, straight, ascending, mostly appressed hairs as well as scattered, shorter, erect, uncinat hairs, lobes with slightly reflexed tip, 3.0–3.5 mm. long, 0.5–1.5 mm. wide; pistil rudiment 0.5 mm. long; filaments 3.0–4.5 mm. long, 0.5 mm. wide; anther sacs 1–2 mm. long, 0.5–0.8 mm. wide.

*Type:* Gaudichaud, Iles Sandwich. (Type deposited in Museum National d'Histoire Naturelle de Paris [P].)

*Range:* Islands of Maui, Molokai, and Lanai, dry gulches and lava flows, 2,200 feet altitude.

*Specimens examined*

*Data complete:* Molokai.—Kamola, *Faurie* 514 (Ho); Slopes of Kolekole, *Forbes* 221-Mo (Ho); Near Laianui, *Degener* 4264 (NY, UC). Lanai.—Mts. near Koele, *Forbes* 74-L (Ho); Kaiholena, *Munro* 136 (Ho); Kaiholena, *Munro* 29 (Ho). Maui.—Nuu, *Forbes* 1915-M (Ho); Auwahi, East Maui, *Rock* 8647 (Ho); Olowalu, *Forbes* 2324-M (Ho); Honuaula, *Hillebrand* (K); Slopes of Haleakala, near Kaupo, *Rock* 8648 (Ho, GH); Waihualale Gulch, slopes of Haleakala, *Forbes* 1824-M (Ho).

*Data incomplete:* Maui.—East Maui, *Hillebrand*; Kawaihai i'uke, Hawaii, *Hillebrand* (K); Hawaii, *Remy* 196 (in part) (P). Data of last two collections are questionable.

This species was published only as a plate in the volume of drawings of plants collected by Gaudichaud on his second voyage, on "La Bonite." He did not describe the group but the publication of the plate legitimizes the name. As a result of his failure to supply a description, faulty interpretation of the group by subsequent authors has been the rule. It was not until his material was studied that the writer was able to apply the name properly. Hillebrand misapplied the name to what is named here *N. angulata* and Wawra also misunderstood the group, applying the name to *N. kauaiensis*. Although Hillebrand's type is not avail-

able, it is likely from the description that his *N. Kahoolawensis* was a Kahoolawe representative of *N. sericea* or, at least, closely related.

The variability in this species is such that a much greater mass of material is necessary before the group can be understood fully. Adequate material may reveal sub-specific entities, for within the material available is some which does have a somewhat different aspect but close examination has failed to reveal any natural bases of segregation. Intensive collecting on Maui, Molokai, and Lanai is necessary before a proper evaluation of the group can be made. The two collections from Lanai have petioles which are half as long as the leaf blades while the leaves of the Maui and Molokai material have petioles one-third or less as long as the leaf blades. In the Maui and Molokai material the main parts of the venation are outlined by very many sub-erect hairs placed almost perpendicularly to the lateral surfaces of these veins. Not all of the Lanai material shows this fringe of hairs. These differences do not seem important enough to justify another group unless subsequent collections show these characters in addition to others of more significance.



FIG. 19. Outlines of leaves to show variation in leaf shape in *Neraudia sericea* Gaud.

*Rock* 8647 and part of *Rock* 8648 are collections of a staminate plant from Maui and are notable because of the occasional presence of a few teeth on the margin of young leaves. In the *Rock* collection, used here for Figure 18, the achenes have a constriction which is more obtuse than is typical. In *Forbes* 2324-M,



the pubescence has a tendency to be directed toward the margin in contrast to being more or less erect as is typical. *Forbes 1915-M* has leaves which are smaller than the average of the other collections, averaging 4 cm. long by 2.5 cm. wide. In this collection, also, the nodes are conspicuous because of the mass of pedicels at each node.

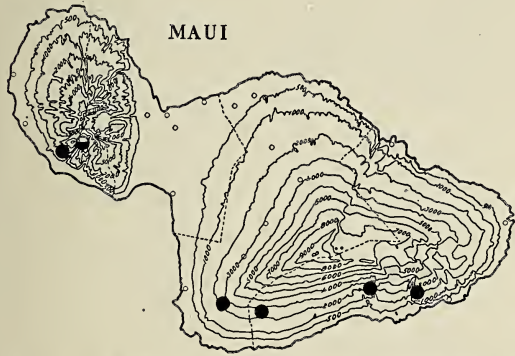


FIG. 20. Distribution of *Neraudia melastomaefolia* Gaud. var. *pallida* Cowan (half-black dots) and *Neraudia sericea* Gaud. on Maui (complete black dots).

Many of the remarks concerning Gaudichaud's plate for *N. melastomaefolia* apply equally well to his plate which stands in lieu of a description of *N. sericea*. The material upon which Gaudichaud based his concept has been carefully examined and the following remarks are based on a comparison of his plate with his material: One of his sheets bears material which is obviously that which was used for the habit sketch, judging from the shape and size of the leaves. The sheet now completely lacks flowers with only scars present to show where flowers were originally situated. The number of scars, however, would indicate far fewer flowers than shown on the plate. The staminate branch shown has the flowers arranged in a most atypical manner and no staminate material collected by Gaudichaud has been received. The beak of the calyx of the pistillate flower is reasonably accurate although that of the fruiting calyx shows this character better. The conspicuous depression at the base of the beak in Gaudichaud's plate is a condition which has not been observed and its existence is

doubtful. The achene shown is not completely mature, as the mature forms usually show a deeper, more acute constriction between the apical and basal portion. The architecturally attractive but biologically inaccurate scroll-work shown at the base of the achene does not exist. Likewise, the swollen, evenly rounded lobes of the basal portion are without basis. The staminate flowers and flower parts are unquestionably copied directly from those on the plate of *N. melastomaefolia*. Every single drawing in the two plates of staminate flower parts is identical (except that the style of shading is different, indicating the work of different illustrators), the calyx lobes and stamens have the same angle between them, their posture is the same, and the pubescence is the same in both. The duplication and the fact that no staminate material of this group collected by Gaudichaud has been received suggest that the artist who made this plate had no material of a staminate plant.

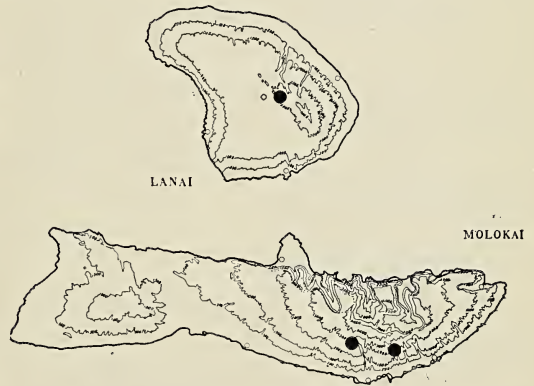


FIG. 21. Distribution of *Neraudia sericea* Gaud. on Molokai and Lanai.

#### COLLECTORS AND COLLECTIONS OF GENUS

Following is a tabular account of the collections made in the genus *Neraudia* and which are cited in this discussion. Each collection is listed alphabetically and chronologically and the group to which it has been assigned by the writer accompanies each. This table has been prepared to facilitate finding the group to which a particular specimen has been assigned.

COLLECTOR AND NUMBER	GROUP TO WHICH ASSIGNED	COLLECTOR AND NUMBER	GROUP TO WHICH ASSIGNED
BAXTER 120	<i>N. melastomaefolia</i> var. <i>uncinata</i>	FAGERLUND AND MITCHELL 842, 1019	<i>N. ovata</i>
BERGMAN No number	<i>N. melastomaefolia</i> var. <i>uncinata</i>	FAURIE 514	<i>N. sericea</i>
CHRISTOPHERSEN 3682, 3685, 3686	<i>N. angulata</i> var. <i>dentata</i>	515	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
COWAN 7, 8, 56, 57, 646, 697, 698	<i>N. melastomaefolia</i> var. <i>uncinata</i>	FORBES Nov. 14-21, 1908	<i>N. melastomaefolia</i> var. <i>uncinata</i>
663, 673, 690, 691, 803, 809	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	398-K, 667-K, 829-K, 865-K	<i>N. melastomaefolia</i> var. <i>pubescens</i>
840	<i>N. angulata</i> var. <i>angulata</i>	No number	<i>N. melastomaefolia</i> var. <i>parvifolia</i>
836, 837, 839, 849	<i>N. angulata</i> var. <i>dentata</i>	2365-M, 2470-M	<i>N. melastomaefolia</i> var. <i>pallida</i>
1054, 1057	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>	1828-O	<i>N. angulata</i> var. <i>angulata</i>
1055, 1056	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	52-K, 1079-K	<i>N. kauaiensis</i> var. <i>kauaiensis</i>
COWAN, <i>et al.</i> 477, 478, 479, 480, 481, 482, 483, 484, 485, 486	<i>N. ovata</i>	28-H, 361-H	<i>N. ovata</i>
COWAN AND ST. JOHN 141, 147, 316, 325	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	74-L, 221-Mo, 1824-M, 1915-M, 2324-M	<i>N. sericea</i>
333	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>	FOSBERG 8774	<i>N. melastomaefolia</i> var. <i>uncinata</i>
COWAN AND SAKIMURA 615, 616, 617	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	9264	<i>N. angulata</i> var. <i>angulata</i>
COWAN, WEBSTER, AND WILBUR 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763	<i>N. angulata</i> var. <i>dentata</i>	FREDERICK 207, 208, 209, 210	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
DEGENER 18190	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>	206	<i>N. melastomaefolia</i> var. <i>parvifolia</i>
18185	<i>N. melastomaefolia</i> var. <i>uncinata</i>	No number	<i>N. ovata</i>
18189	<i>N. melastomaefolia</i> var. <i>pubescens</i>	GAUDICHAUD 208	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
12803, 12235, 17192, 17506, 17647, 18183, 18189, 18191, 18192	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	No number	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
18182	<i>N. angulata</i> var. <i>angulata</i>	No number	<i>N. ovata</i>
19181	<i>N. angulata</i> var. <i>dentata</i>	No number	<i>N. sericea</i>
18187	<i>N. ovata</i>	HELLER 2792	<i>N. melastomaefolia</i> var. <i>pubescens</i>
4264	<i>N. sericea</i>	2847	<i>N. kauaiensis</i> var. <i>Helleri</i>
17117, 18184	<i>N. melastomaefolia</i> var. <i>Gaudichaudii</i>	2881	<i>N. kauaiensis</i> var. <i>kauaiensis</i>
DONAGHJO <i>N. melastomaefolia</i> var. <i>melastomaefolia</i>		HILLEBRAND MACCAUGHEY No number	<i>N. angulata</i> var. <i>dentata</i>
		MACDANIELS 887	<i>N. melastomaefolia</i> var. <i>pubescens</i>
		926	<i>N. melastomaefolia</i> var. <i>parvifolia</i>
		No number	<i>N. ovata</i>



COLLECTOR AND NUMBER	GROUP TO WHICH ASSIGNED	COLLECTOR AND NUMBER	GROUP TO WHICH ASSIGNED
MANN AND BRIGHAM		RUSS	
220	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>	No number	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
624 (part)	<i>N. melastomaefolia</i> var. <i>pubescens</i>	No number	<i>N. melastomaefolia</i> var. <i>parvifolia</i>
624 (part)	<i>N. kauaiensis</i> var. <i>kauaiensis</i>	No number	<i>N. angulata</i> var. <i>dentata</i>
MEEBOLD		ST. JOHN	
No number	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	22269, 22270, 22568	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
No number	<i>N. ovata</i>	12120, 20251	<i>N. melastomaefolia</i> var. <i>uncinata</i>
MUNRO		22890, 22891	<i>N. melastomaefolia</i> var. <i>pubescens</i>
29, 136	<i>N. sericea</i>	9933, 10422, 10599	<i>N. melastomaefolia</i> var. <i>parvifolia</i>
NITTA		SEEMAN	
37	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	2260	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>
REMY		SELLING	
196	<i>N. sericea</i>	3097	<i>N. melastomaefolia</i> var. <i>pubescens</i>
197	<i>N. melastomaefolia</i> var. <i>melastomaefolia</i>	3203	<i>N. ovata</i>
198	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	3363, 3669	<i>N. melastomaefolia</i> var. <i>parvifolia</i>
ROCK		3697	<i>N. melastomaefolia</i> var. <i>Gaudichaudii</i>
368, 568, 626, 796, 8838, Dec. 1919	<i>N. melastomaefolia</i> var. <i>uncinata</i>	SKOTTSBERG	
2374, 5327, 9007	<i>N. melastomaefolia</i> var. <i>pubescens</i>	993	<i>N. melastomaefolia</i> var. <i>pubescens</i>
17084	<i>N. melastomaefolia</i> var. <i>parvifolia</i>	673, 1956, 1962	<i>N. ovata</i>
5323, 5922, 17111	<i>N. kauaiensis</i> var. <i>kauaiensis</i>	SUEHIRO	
4015, 8776	<i>N. ovata</i>	No number	<i>N. melastomaefolia</i> var. <i>uncinata</i>
8647, 8648	<i>N. sericea</i>	WEBSTER	
		1603	<i>N. melastomaefolia</i> var. <i>Gaudichaudii</i>

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A Preliminary Report on *Parathunnus sibi* in Hawaiian Waters  
and a Key to the Tunas and Tuna-like Fishes of Hawaii<sup>1</sup>

• VERNON E. BROCK<sup>2</sup>

THE BIGEYE TUNA, *Parathunnus sibi* (Temminck & Schlegel), is an important part of the catch of large tunas from Hawaiian waters (Table 1), and yet it is so little known that it seems desirable to publish the preliminary data obtained by the Division of Fish and Game of Hawaii concerning it. These data may be conveniently considered in three categories: (1) field identification of the species principally by external characters, (2) morphometric data, which may be useful in later racial studies as the species is an important one in Japanese as well as Hawaiian landings (Shapiro, 1948: Table 8), and (3) some ecological information based largely on the characteristics of the fishery for the species in Hawaii. Some incidental in-

formation on the commercial importance of this species and on the method of taking it is also given.

*Parathunnus sibi* has been reported from Hawaiian waters by Kishinouye (1923: 444), Jordan and Evermann (1926: 17), and Fowler (1928: 134). Kishinouye's report was hearsay and the descriptions by Jordan and Evermann and by Fowler are hardly sufficient for certain identification. Based on a single sight identification in the San Pedro markets, Kishinouye also reported the occurrence of this species on the west coast of North America. Since then Godsil and Byers (1944: 105-119) have discussed in detail two small specimens from the west coast of Central America. *P. sibi*, originally described from Japanese waters, would seem to span the tropical Pacific in its range.

In the spring of 1948, during a morphometric study of Hawaiian yellowfin tuna, *Neothunnus*

<sup>1</sup>Research Paper No. 8, Cooperative Fisheries Research Staff, Territorial Board of Agriculture and Forestry and the University of Hawaii. Manuscript received December 10, 1948.  
<sup>2</sup>Director, Division of Fish and Game, Board of Agriculture and Forestry, Honolulu, Hawaii.

TABLE 1  
LANDINGS OF YELLOWFIN AND BIGEYED TUNA IN THE TERRITORY OF HAWAII, 1947 AND 1948

MONTH	YELLOWFIN		BIGEYED	
	1947	1948	1947	1948
	pounds	pounds	pounds	pounds
January.....	58,277	87,661	14,496	64,434
February.....	70,494	92,664	24,079	108,374
March.....	21,955	88,671	28,472	78,065
April.....	89,652	72,469	24,176	78,739
May.....	86,843	60,209	13,661	40,407
June.....	161,988	123,014	10,086	26,644
July.....	173,673	130,005	14,858	19,761
August.....	197,949	132,629	15,646	15,616
September.....	139,831	96,162	7,077	21,835
October.....	101,675	71,703	14,455	40,808
November.....	95,396	102,483	62,393	76,526
December.....	116,616	100,441	101,269	99,128
Totals.....	1,314,349	1,158,111	330,668	670,337

*macropterus*, the identification of the species subsequently determined to be *Parathunnus sibi* proved to be most puzzling until an examination of internal characters was made. It was possible, by inspection, to divide the catch of large tunas auctioned in the Honolulu fish markets into two kinds, both of which, insofar as external characters went, agreed substantially with the available descriptions of *Neothunnus macropterus*. It was suspected that one of the kinds was *Parathunnus* because of its large eye, large head, coarser scalation, and thick, heavy body. However, the available descriptions of *Parathunnus* differed in a number of respects from these fish. Although Kishinouye mentioned that the pectoral fin was relatively shorter in larger fish, Kishinouye as well as Godsil and Byers described *Parathunnus mebachi* Kishinouye, which is here regarded as a synonym of *Parathunnus sibi* (Temmnick & Schlegel), as having a long pectoral fin reaching beyond the anal insertion and to or beyond the anal fin base. The Hawaiian fish examined by me have a pectoral fin which is shorter than that of *Neothunnus* of comparable size and which usually does not reach as far as the insertion of the anal fin. Kishinouye described the anal finlets of *P. sibi* as grayish with a yellow margin; Fowler, who was familiar with Hawaiian material, reported that the finlets were without yellow markings. However, the finlets examined by me have been yellow or orange-yellow with black borders. A 100-pound specimen, the smallest available after several weeks of checking the markets, was purchased for dissection. A study of the internal characters of taxonomic importance—such as the arrangement of the cutaneous circulatory system and the marginal striations on the liver—indicated that the fish was a *Parathunnus*, probably *P. sibi* (Temmnick & Schlegel).

One of the most obvious differences between the Hawaiian specimens of *P. sibi* and the descriptions of this species in literature is, as has been mentioned above, in the relative length of the pectoral fin. Kishinouye's Figure 47 (1923:

Pl. 27) shows the tip of the pectoral fin reaching to a vertical line beyond the anal fin base. The photograph of one of the two specimens described by Godsil and Byers (1944: Fig. 59) shows approximately the same relationship. The pectoral fin in the Hawaiian *Parathunnus*, at least in the size range examined by the Division of Fish and Game staff, hardly reaches a vertical line through the insertion of the second dorsal fin, and does not reach the anal insertion at all.

There is an apparent difference in the relative length of the pectoral fins of Hawaiian specimens and of species described in the literature. This is probably attributable to the great differences in size range of fish examined in Hawaii and elsewhere.

However, if the assumption is made that the relationship between the pectoral fin length and total body length is linear when logarithms of the body length are used, then the difference between the Hawaiian material and the available descriptions may be reconciled. Since it seemed to fit his data best, Schaefer (1948) assumed a relationship of this kind between pectoral fin length and body length for *Neothunnus*. Though no proof of the assumption will be offered here for *Parathunnus*, it seems logical to assume that a similar relationship may exist. Where two variables are related linearly when the logarithms of one of them are used, then with an increase in the variables, the variable transformed into logarithmic form will increase much more rapidly on an arithmetical basis than the other. Hence as the fish becomes longer, the pectoral fin becomes relatively shorter, and conversely the smaller fish would have, therefore, relatively much longer pectoral fins. The size range of the Hawaiian *Parathunnus* here reported was 1,191 to 1,900 mm. The specimen figured by Kishinouye (1923), and referred to as immature, was approximately 750 mm. long as estimated by the scale indicated on the plate. The two specimens examined by Godsil and Byers (1944) were 569 mm. and 910 mm. in length, respectively. A line fitted to pectoral fin length and the logarithms of total



length by the method of least squares, when projected for the sizes smaller than those included in the Hawaiian data, indicates that the smaller fish would have, relatively, a much longer pectoral fin. It would seem futile, therefore, to diagnose tunas by such characters as fin lengths without first examining the fins throughout the size range of a species.

Table 2 contains measurements and counts of 20 specimens made in the Honolulu fish markets during the early summer of 1948. The method of measuring and counting described by Godsil and Byers (1944: 125–128) was followed. All measurements were made with large calipers with one fixed and one sliding arm, held parallel. As may be noted in Table 2 characters listed were not determined for all fish. This was because the measurements were made during an auction of the fish, the only practical time and place in which to measure them, and fish would occasionally be purchased and butchered before measurements could be completed. Similarly, it was not possible to determine the sex of all fish since sexes were determined by observation while a dealer butchered his recently acquired merchandise.

The computations for the regression lines for the various characters given in Table 2 have not been given here, since such comparisons of regression lines can be made with comparable data obtained for other localities and by statistical methods that seem appropriate. It does not seem worthwhile to suggest the design of a statistical scheme of analysis here by computing part of it, especially since most workers would prefer to take the field data as given in Table 2 as their starting point.

Table 1 and Figure 1 show that the largest landings of *Parathunnus* are made during the winter months. Many of the fishermen alter their gear during this period to increase the catch of this species. The Hawaiian catch of *Parathunnus* is taken on flagline or longline gear. This is an unanchored set line with hooks at approximately 30-fathom intervals and floated by buoys in deep water. The hooks are attached

to leaders up to 20 fathoms long in fishing for *Neothunnus* during the summer months. In fishing for *Parathunnus*, and *Neothunnus* too, during the winter months these leaders are often lengthened several fathoms. For a detailed description of longline gear see Shapiro (1948: 40–44). *Parathunnus*, aside from the occasional capture of small individuals, is rarely taken by surface fishing techniques such as trolling or fishing with live bait.

This information would imply that *Parathunnus* is not a surface fish but that, at least during daylight, it feeds in the layers below 20 fathoms. The large eye characteristic of the species would lend weight to such an assumption. Kishinouye's discussion (1923: 444–445) of the habits of the species likewise indicates that it is not a surface fish but may approach nearer the surface at night.

*Parathunnus*, as taken in the Hawaiian flagline fishery, is a large tuna. Examples under 80 pounds are rare; the average weight of the specimens landed during January to September, 1948, for example, was 157.8 pounds. The maximum weight of this species landed in Hawaiian waters approaches or exceeds 300 pounds. Kishinouye, however, gives a maximum weight of 86 kilograms (190 pounds) for Japanese examples, but as he states that a fish of this weight would be about 2 meters long, it is probable that his estimate of the maximum weight is in error. A 2-meter long specimen with the body proportions of the Hawaiian fish would weigh about 334 pounds.

The fact that *Parathunnus* is rarely taken by surface fishing methods has some interesting connotations. The present fishing grounds for the species in the Pacific are those grounds on which flagline fishing gear is employed. Although in Hawaii *Parathunnus* is from one-half to two-thirds as important as *Neothunnus* in the landings of large tunas, in Japanese landings (Shapiro, 1948, table 8) in some years, it was far more important than *Neothunnus*. Aside from the two specimens discussed by Godsil and Byers (1944: 105–119) and one

TABLE 2  
MORPHOMETRIC DATA (LISTED IN ASCENDING ORDER BY LENGTH) FOR 20 HAWAIIAN PARATHUNNUS\*

Total length .....	1,191	1,236	1,279	1,290	1,342	1,372	1,373	1,422	1,470	1,475	1,495	1,542	1,570	1,592	1,593	1,670	1,697	1,760	1,783	1,900
Date† .....	4/14	4/14	6/2	4/16	6/2	4/16	4/16	6/2	4/12	4/13	6/2	5/25	5/6	5/25	3/24	4/12	5/13	5/17	4/14	6/4
Weight .....	83	90	98	101	115	137	128	125	163	151	145	164	180	181	189	214	201	248	261	275
Head length .....	354	369	372	382	404	404	409	410	447	429	447	450	457	461	467	480	469	497	516	533
From snout tip to 2nd dorsal insert .....	649	679	686	712	734	743	763	748	823	811	825	819	847	862	858	884	878	916	940	989
From snout tip to anal insert.....	730	759	774	779	834	837	844	862	929	901	905	919	940	998	970	.....	1,024	1,026	1,083	1,114
From snout tip to pectoral insert..	359	365	380	385	397	400	406	419	450	420	446	446	448	457	471	472	468	487	514	526
Greatest body depth.....	331	339	356	353	352	391	509	369	412	425	382	419	417	411	425	.....	435	487	480	480
Place of greatest body depth.....	7-D	7-D	8-D	7-D	6-D	9-D	9-D	7-D	7-D	6-D	7-D	7-D	7-D	8-D	.....	.....	4-D	6-D	8-D	7-D
Length base 1st dorsal.....	315	331	321	329	346	359	349	336	397	377	382	383	395	412	377	.....	398	428	450	500
Anal fin length.....	161	200	195	187	188	196	176	223	232	214	209	225	242	243	260	252	252	274	266	268
2nd dorsal fin length.....	149	192	200	195	205	193	183	215	257	231	214	233	253	238	.....	245	254	278	264	263
Spread of caudal.....	431	465	467	432	480	469	460	495	.....	525	522	598	579	566	635	.....	642	688	719	707
Pectoral fin length.....	330	401	374	357	368	357	341	383	366	366	371	377	386	373	382	380	370	396	413	351
Gill raker count.....	9/19	7/18	9/19	9/18	9/19	8/19	8/19	9/18	.....	6/20	9/20	9/19	8/18	7/20	9/18	.....	9/18	7/17	8/18	8/18
Sex .....	♀	♂	.....	♀	.....	.....	.....	.....	♂	.....	.....	♀	.....	.....	♀	♀	♂	.....	♂	.....

\* Weights are in pounds and lengths are in millimeters. Place of greatest body depth (7-D, 8-D, etc.) refers to the seventh or eighth dorsal spine. In the gill raker count (9/19, 7/18, etc.) the first number refers to the number of gill rakers on the upper limb of the gill arch, the second number to the number of gill rakers on the lower limb.  
† Measurements made on dates indicated in March, April, May, and June, 1948.



mentioned by Kishinouye (1923: 444), *Parathunnus* is not known from the eastern tropical Pacific, yet it may well be abundant in the tuna grounds now exploited by the California tuna fishermen. Its abundance in the eastern Pacific will not be determined until fishing gear capable of taking it is tried in those waters.

The *Parathunnus* fishery serves to point up the fact that the fishing techniques now available for taking oceanic species may be inadequate to exploit these species in proportion to their actual abundance in the sea. There is a possibility that in some areas now fished, marine food resources of considerable magnitude, not only untapped but unknown, may exist.

KEY TO THE TUNAS AND TUNA-LIKE FISHES OF HAWAII

The following key is to the tunas and tuna-like fishes reported from Hawaiian waters. Those species marked with an asterisk are commonly taken about the Hawaiian Islands; those not so marked either do not occur in this area, or else are rare, and have not been seen by the author among fish landed at any Hawaiian port.

Two species, *Semathunnus itosibi* (Jordan and Evermann) and *Grammatorcynus thompsoni* (Fowler), described from the Hawaiian Islands are not included in the key. *Semathunnus itosibi* = *Neothunnus macropterus*, as understood here; *Grammatorcynus thompsoni* is probably a scomberomorid or gempylid synonymous with *Lepidocybium flavo-brunneum* (Smith).

- 1. First dorsal fin with 10 to 18 spines; body not over five times as long as greatest depth ..... 2
- First dorsal fin with about 25 spines; body long and slender, at least six and a half times as long as greatest depth. Ono .....  
.....\**Acanthocybium solandri* (Cuvier & Valenciennes)
- 2 (1). Body completely scaled, scales may be enlarged in corselet and on lateral line ..... 5
- Body naked, without scales, except for the scaly corselet and lateral line ..... 3
- 3 (2). The last spine in the first (spinous) and the first ray in the second (soft rayed) dorsal fins close to-



FIG. 1. Number of tuna caught by flagline in Hawaiian waters during 1948.

- gether, separated by a distance equal to about one-fifth of head length ..... 4
- The first and second dorsal fins far apart, separated by a distance equal to about one-half the head length or more. Frigate mackerel ..... \**Auxis thazard* (Lacepede)
- 4 (3). Four dark longitudinal stripes present on lower surface below lateral line of side and on belly. Aku ..  
..... \**Katsuwonus pelamis* (Linné)  
No dark longitudinal stripes below lateral line, about 12 dark wavy streaks on back. Kawakawa....  
..... \**Euthynnus yaito* (Kishinouye)
- 5 (2). Dorsal finlets with some yellow, usually largely yellow ..... 7
- Dorsal finlets without any yellow markings ..... 6
- 6 (5). Spines in first dorsal fin 14 or fewer in number. Bluefin tuna .....  
..... \**Thunnus thynnus* (Linné)  
Spines in first dorsal fin 18 in number. Bonito ..... \**Sarda chilensis* (Cuvier & Valenciennes)
- 7 (5). Gill rakers on upper and lower branch of first gill arch fewer than 32 in number, usually fewer than 30 ..... 8
- Gill rakers on upper and lower branch of first gill arch 36 to 39 in number; pectoral fin does not reach to a vertical through second dorsal fin insertion; anal finlets silvery. Black tuna, Maguro ....  
..... \**Thunnus orientalis* (Temmnick & Schlegel)
- 8 (7). Gill rakers on upper and lower branch of first gill arch 24 or more in number; air bladder present; pectoral fin reaches, in most of the species included here, to or beyond a vertical through the last spine of the first dorsal fin ..... 9
- Gill rakers on upper and lower branch of first gill arch 23 or fewer in number; no air bladder; pectoral fin does not reach to a vertical through caudal end of first dorsal fin; size small, usually less than 25 pounds .....  
..... \**Kishinoella rara* (Kishinouye)
- 9 (8). Anal finlets with yellow or orange color; a vertical line through tip of pectoral fin usually falls anterior to end of anal fin base, at least in larger specimens of over 70 or 80 pounds ..... 10
- Anal finlets dusky without yellow or orange color; a vertical line through tip of pectoral fin usually falls posterior to end of anal fin base; size medium to small, rarely more than 70 or 80 pounds, usually much less. Albacore ....  
..... \**Germo alalunga* (Gmelin)
- 10 (9). Dorsal and anal finlets a clear yellow, very narrowly black edged; some large individuals of this species may have elongate second dorsal and anal fins, reaching nearly to the caudal fin or beyond; number of gill rakers on upper and lower limb of first gill arch usually 30 (27 to 31); liver without marginal striations. Yellowfin tuna, Ahi .....  
..... \**Neothunnus macropterus* (Temmnick & Schlegel)
- Dorsal and anal finlets with a broad black border, anal finlets often with an orange rather than yellow color; second dorsal and anal fins never greatly elongated, a little longer than the longest spines of the first dorsal fin and much shorter than pectoral fin; number of gill rakers on upper and lower limb of first gill arch usually 27 (24-29); liver with marginal striations. Bigeye tuna .....  
..... \**Parathunnus sibi* (Temmnick & Schlegel)

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# NOTES

## Arthropods of Potential Medical and Veterinary Importance from Ponape, Caroline Islands

The list presented here is based on a collection made by the writer on the island of Ponape during January and February, 1948.

### Mites

*Trouessartia rosterii* Berlese; host—starling (*Aplonis opaca ponapensis*). *Myocoptes musculinus* (Koch); host—mouse. *Radfordia affinis* (Poppe); host—mouse. *Echinolaelaps echidninus* (Berlese); host—rat. *Laelaps nuttalli* Hirst; host—rat.

### Ticks

*Boophilus* sp., probably *B. annulatus australis* (Fuller) previously reported by Alicata (1948, *Pacific Sci.*); host—dairy cow. *Amblyomma* sp.; host—domestic pig.

### Sucking lice

*Pediculus humanus* var. *capitus* Degeer. *Hæmatopinus adventicius* Newm.; host—domestic pig.

### Biting lice

*Lipeurus caponis* (L.), *Menopon gallinae* (L.), and *Oxylipurus angularis* Peters; host—wild chicken (*Gallus gallus*). *Actornithophilus epiphanes* (K. & Ch.); host—tern (*Anous stolidus pileatus*). *Myrsidea* sp.; host—starling (*Aplonis opaca ponapensis*).

### Biting midge

*Culicoides esakii* Tokunaga. Annoying in the forests of the interior.

### Mosquitoes

*Aedes aegypti* (L.); *Aedes* sp.; *Aedes* sp.; *Culex quinquefasciatus* Say; *Culex annulirostris* Skuse; *Culex* sp. (See paper by Knight and

Hurlbut in *Jour. Washington Acad. Sci.*, 1949, in press.)

### Filth-frequenting flies

*Chrysomya megacephala* (F.); *Chrysomya rufifacies* (Macq.); *Chrysomya* (*Microcalliphora*) *nigripes* Aub.; *Hemipyrellia tagaliana* (Big.); *Musca domestica* L.; *Musca sorbens* Wd.; *Ophyra nigra* (Wd.); *Ophyra chalcogaster* (Wd.); *Sarcophaga peregrina* (R.D.); *Sarcophaga knabi* Pk.

### Biting flies

*Stomoxys calcitrans* (L.); *Siphona irritans* (L.).

### Parasitic flies

*Ornithoctona plicata* (Olfers); host—pigeon (*Ducula oceanica townsendi*). *Ornithoica pusilla* (Schin.); hosts—wild chicken (*Gallus gallus*) and starling (*Aplonis opaca ponapensis*). *Cyclopodia* sp.; host—fruit bat.

### Fleas

*Ctenocephalides canis* (Bouche); hosts—dog, pig, goat.

I wish to acknowledge, with thanks, the assistance of individuals who made identifications of the above material: mites, E. W. Baker; fleas and lice, C. F. W. Muesebeck; parasitic flies and biting midge, Alan Stone; filth-frequenting flies, C. W. Sabrosky; birds, Herbert Friedman. Also I wish to express my appreciation for the assistance given by John I. Thomas, Chief Hospitalman, U. S. Navy, in collecting the material and preparing the vertebrate specimens.—Herbert S. Hurlbut, Commander, MSC, USN, Naval Medical Research Institute, Bethesda, Maryland.



## News Notes

Building of the new laboratory of the Pacific Oceanic Fishery Investigations is expected to begin in July, 1949. The laboratory, which is to be the headquarters of POFI, will be erected on the campus of the University of Hawaii. A temporary headquarters office is now located in Room 811, Appraisers Building, 630 Sansome Street, San Francisco 11, California. First appointments to the staff of POFI include: Oscar E. Sette, Director; Fred F. Johnson, Assistant Director; Milner B. Schaefer, Chief, Section of Biology and Oceanography; Carl B. Carlson, Chief, Section of Exploratory Fishing; and Charles Butler, Chief, Section of Technology.

Elwood C. Zimmerman, Associate Entomologist of the Experiment Station, Hawaiian Sugar Planters' Association, and Curator of Entomology, Bernice P. Bishop Museum, has received a special appropriation from the Hawaiian Sugar Planters' Association to aid him in completing additional volumes of his *Insects of Hawaii*, a project of the Experiment Station's Department of Entomology. Mr. Zimmerman is now at the British Museum of Natural History studying the types of Hawaiian insects deposited there in collections made by early visitors to Hawaii.

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, have been received. Each report includes a list of all those published, their distribution, and rules for obtaining them.

*Wildlife Conservation in Japan*. Report No. 116. 24 pp., 7 figs.

*Aquatic Resources of the Ryukyu Area*. Report No. 117. 54 pp., 14 figs., 13 tables.

*Waterfowl of Japan*. Report No. 118. 106 pp., 38 figs., 1 table.

[*Important Trees of Japan*. Report No. 119. Not received.]

*Coal Fields of Eastern Honshu, Japan*. Report No. 120. 34 pp., 8 figs., 1 pl., 3 tables.

An announcement has been received telling of the change in name of the journal *Terrestrial Magnetism and Atmospheric Research*. Beginning with Volume 54, No. 1, March, 1949, this international quarterly will be known as the *Journal of Geophysical Research*, and will "endeavor to cover a broad range of subjects on geophysical research directed toward scientific goals, as distinguished from applied or industrial geophysics." The journal will be edited by Merle A. Tuve, with the assistance of Walter E. Scott, and the advice and experienced help of J. A. Fleming, who has been associated with the publication of *Terrestrial Magnetism and Atmospheric Research* almost since its inception in 1896 and who was its able editor from 1928 to 1948. The Editorial Office of the journal is at 5241 Broad Branch Road, N. W., Washington 15, D. C. The journal is published by the Johns Hopkins Press, Baltimore 18, Maryland, and subscriptions (at \$3.50 a year) should be directed to that address.

The Hawaiian Botanical Society commemorated its twenty-fifth anniversary on May 2, 1949, with a program titled "Hawaiian Botany Twenty-Five Years Ago" and by election of the following charter members to the first honorary life memberships in the Society: Elizabeth D. W. Brown, F. B. H. Brown, E. L. Caum, F. G. Krauss, Maude F. Lyon, Harold L. Lyon, G. A. McEldowney, Elizabeth B. MacNeil, Willis T. Pope, and O. H. Swezey.

Among papers to be included in forthcoming issues of *Pacific Science* are:

Notes on New Zealand Marine Algae I—Victor W. Lindauer.

A Catalogue of the Heterocerous Lepidoptera of French Oceania—P. E. L. Viette.

Ocean Temperatures of the Hawaiian Island Area—Dale F. Leipper.

The Status of Steller's Albatross—O. L. Austin.

Three papers on luminescence in marine fishes—Yata Haneda.

*A Treatise on Marine Ecology and Paleoecology.*—This is the eighth of a series of publications designed to aid in the preparation of a treatise on marine ecology and paleoecology. Like the previous volumes, it includes notes on current activities, bibliographies, papers, and abstracts of pertinent papers as well as some of the completed units of the proposed treatise.

LADD, HARRY S., *et al.* Report of the Committee on a Treatise on Marine Ecology and Paleoecology, 1947–1948. No. 8, December, 1948. Division of Geology and Geography, National Research Council, 2101 Constitution Ave., Washington 25, D. C. 117 pp. \$1.00.

The former editor-in-chief of *Pacific Science*, A. Grove Day, has collaborated with Carl Stroven, University of Hawaii Librarian, in the preparation of a delightful anthology of the literature of the Pacific. It has just been released by the publisher, Macmillan Company, under the title, *The Spell of the Pacific: An Anthology of Its Literature*. It runs the gamut from Captain Bligh and Charles Darwin to James Norman Hall and Charles Nordhoff. All interested in the Pacific in any way will find much of interest in the 940 pages of this volume.

STROVEN, CARL, AND A. GROVE DAY. *The Spell of the Pacific: An Anthology of Its Literature*. xx + 940 pp. The Macmillan Company, New York, 1949. \$6.50.



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## SUGGESTIONS TO AUTHORS

Contributions to Pacific biological and physical science will be welcomed from authors in all parts of the world. Manuscripts may be addressed to the Editor-in-Chief, *PACIFIC SCIENCE*, University of Hawaii, Honolulu 14, Hawaii, or to individual members of the Board of Editors. Use of air mail for sending correspondence and brief manuscripts from distant points is recommended.

Manuscripts will be acknowledged when received and will be read promptly by members of the Board of Editors or other competent critics. Authors will be notified of the decision reached as soon as possible.

Manuscripts of any length may be submitted, but it is suggested that authors inquire concerning possibilities of publication of papers of over 30 printed pages before sending their manuscript. Authors should not overlook the need for good brief papers presenting results of studies, notes and queries, communications to the editor, or other commentary.

### PREPARATION OF MANUSCRIPT

Although no manuscript will be rejected merely because it does not conform to the style of *PACIFIC SCIENCE*, it is suggested that authors follow the style recommended below and exemplified in the journal.

**Title.** Titles should be descriptive but brief. If a title runs to more than 40 characters, the author should also supply a "short title" for use as a running head.

**Manuscript form.** Manuscripts should be typed on one side of standard-size, white bond paper and double-spaced throughout. Pages should be consecutively numbered in upper right-hand corner. Sheets should not be fastened together in any way, and should be mailed flat. Inserts should be either typed on separate sheets or pasted on proper paper, and point of insertion should be clearly indicated.

**Original copy and one carbon copy** of manuscript should be submitted. The author should retain a carbon copy. Although due care will be taken, the editors cannot be responsible for loss of manuscripts.

**Introduction and summary.** It is desirable to state the purpose and scope of the paper in an introductory paragraph and to give a summary of results at the end of the paper.

**Dictionary style.** It is recommended that authors follow capitalization, spelling, compoundings, abbreviations, etc., given in *Webster's New International Dictionary* (unabridged), second edition; or, if desired, the *Oxford Dictionary*. Abbreviations of titles of publications should, if possible, follow those given in U. S. Department of Agriculture *Miscellaneous Publication* 337.

**Footnotes.** Footnotes should be used sparingly and never for citing references (see later). Often, foot-

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## The Status of Steller's Albatross

OLIVER L. AUSTIN, JR.<sup>1</sup>

THE SHORT-TAILED ALBATROSS or Steller's Albatross, *Diomedea albatrus*, the largest and handsomest of the three North Pacific albatrosses, was abundant at the turn of the present century, but has become so rare during the past two decades that it may soon be extinct, if it is not already so. Because it seems unlikely that we will ever learn more about it at first hand, this paper attempts to clarify our knowledge of the species by examining and evaluating all the known written record. For a bird that so recently was relatively common, accurate data are remarkably scarce in literature. Much of the most pertinent and illuminating information about it is written in Japanese. As these writings have never before been translated or summarized, the data they contain have heretofore been unavailable to western scientists.

Steller's Albatross was discovered by the famous German naturalist whose name it bears, during his travels with Commander Bering in Kamchatka and the Bering Sea in the 1740's. It was described and named in 1780 by P. S. Pallas, in his *Spicilegia Zoologica*, from a specimen taken off Kamchatka. Since then ornithologists, other than the Japanese, have been able to do little more than describe the physical features of the scanty specimen material available—most of it taken at sea during the non-breeding season—and to delineate its former habitat from the data on the labels of these specimens, and from bones found in prehistoric shell-heaps and kitchen middens in Oregon and California. Dur-

ing the non-breeding season the species apparently ranged widely over the North Pacific, from the China coast northward to Kamchatka and the Bering Sea (northernmost record, Norton Sound, Alaska), and down the Pacific coast of North America to lower California.

We now know, as will be shown in detail later, that the breeding range of Steller's Albatross was limited to isolated oceanic islets south of Japan. It bred, definitely, in the southern Izus, northern Bonins, and southern Ryukyus, and perhaps, though confirmatory specimen evidence is lacking, in the Pescadores and Daito Islands as well. All western accounts to date, however, list the species as breeding only in the Bonins and, erroneously, on Wake Island.

The inclusion of Wake in the breeding range of the species is apparently based on the writings of Titian R. Peale, who visited Wake in 1841 as naturalist on the United States exploring expeditions which cruised Pacific and Antarctic waters from 1838 to 1842 under Lt. Charles L. Wilkes. Peale quarreled with Wilkes shortly after the expedition's return and the latter accordingly refused to allow him to publish his findings. His notes were eventually incorporated by John Cassin in his report on the expedition's specimen material published 15 years later, in 1858. Peale's and Cassin's identification of the birds on Wake has been accepted without question and has been quoted widely ever since. On careful re-examination of the evidence, however, it becomes quite apparent that Peale's notes on the Wake Island albatrosses refer not to *D. albatrus*, but to the Laysan Albatross, *D. immutabilis*, which was not recognized as a distinct species until 1893, half a century later.

<sup>1</sup>Head, Wildlife Branch, Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers. Published with permission of Lt. Col. H. G. Schenck, Chief, Natural Resources Section. Abstract read at Pacific Science Congress, Auckland, N. Z., February 21, 1949. Manuscript received March 23, 1949.

No specimens are available today to verify the identification of the albatrosses Peale found nesting on Wake. If Peale collected any specimens there Cassin does not mention the fact, and no other naturalist visited the colony before it was wiped out by feather hunters later in the 19th century. Peale mentions finding both light and dark colored albatrosses on Wake, but he believed the dark birds (ostensibly the Black-footed Albatross, *D. nigripes*) to be the immature form of the light colored bird, which Cassin lists as *D. brachyura* (a synonym of *D. albatrus*), and which he states was the only albatross species encountered by the expedition in the North Pacific. Most significant, however, are Peale's measurements of the albatross eggs he found on Wake, which Cassin gives as 4.2 x 2.6 inches. These are smaller than those of typical *D. albatrus* from the Bonins and Torishima, but well within the range of those of *D. immutabilis* from Laysan.

Had Steller's Albatross ever bred on Wake, it is difficult to account for its absence on the Marcus Island rookery, which was visited and reported on by both American and Japanese naturalists before it, too, succumbed to the attentions of the feather hunters in the early 20th century. Marcus Island lies almost midway between Wake and the nearest verified breeding grounds of *D. albatrus* in the Bonins, and is the only spot of land in that 1,700-mile expanse of sea. Both Bryan (1903: 77-116) and Namiye (1905: 219) report *D. immutabilis* and *D. nigripes* as having bred on Marcus, but no record exists of *D. albatrus* ever having occurred there. Hence, it is unlikely that Steller's Albatross ever bred eastward of the Bonin-Izu Island chain.

The first unquestionable record of the nesting of Steller's Albatross is the five eggs in the Pryer Collection, which Seebohm (1890: 105) says "are labelled as having come from the Bonin Islands." These eggs apparently were collected by P. A. Holst, who probably collected at the same time the 12 eggs from the Bonins that are in the British Museum. Holst himself never

wrote a word of his experiences in the Bonins, and no one knows on which of the islands he collected the eggs. Bent (1922: 7) gives the average measurements of 43 eggs in various museums in America and Europe, but he gives egg collection dates only for the Bonins and adds, "I can not find any description of the downy young and doubt if they have ever been collected."

Nothing, other than Peale's brief and misapplied account, has ever been written in western literature of the species' breeding habits. No occidental ornithologist other than Holst has ever, to our knowledge, been on its breeding grounds. At least, if anyone has, he has left no written record of his experiences. La Touche (1895: 327) encountered Steller's Albatrosses in the Pescadores and says that on February 10, 1894, "they absolutely swarmed" about his ship when it was anchored off Fisher Island.<sup>2</sup> But he found no sign of the bird when he went ashore there, and in writing of the species 40 years later (1935: 429), he lists it as breeding only in the Bonins.

The *Hand-List of Japanese Birds* for 1932 and 1942 add the following breeding localities, but without further elaboration or substantiation: Torishima in the southern Izu, Kitano-shima and Nishinoshima in the Bonins, Kobisho and Agincourt in the southern Ryukyus, and the Pescadores. Referring back to the original Japanese papers for the evidence on which these statements are based, we find some of them to be vague and inadequately documented. These papers contain, nevertheless, information which adds greatly to our knowledge of the species, as the following sections show.

In Japanese, incidentally, albatrosses in general are known as "aho-dori" or "baka-dori," both of which mean "fool-bird." These appellations, which date back to medieval times and have become integral, autochthonous parts of the language, were undoubtedly engendered by the birds' manifest stupidity and tameness, par-

<sup>2</sup> Byo-o-to, 23° 36' x 119° 30', one of the larger islands in the center of the group.



ticularly on their breeding grounds. Modern usage by contemporary Japanese ornithologists restricts the common name "aho-dori" to Steller's Albatross. The Laysan Albatross is now referred to specifically as the "Ko-aho-dori" (small albatross), while for the Black-footed Albatross, its English name has been borrowed and translated as "Kuro-ashi-aho-dori."

#### TORISHIMA

The largest and most famous colony of Steller's Albatross ever known flourished on Torishima (literally "Bird Island"),<sup>3</sup> the southernmost of the Seven Islands of Izu, an isolated islet about 300 miles due south of Tokyo. Torishima is actually the conical top of a volcano, almost circular, and about 1½ miles in diameter, projecting about 1,150 feet above the sea surface. Its shore line is rimmed with cliffs that make landing difficult except during the calmest weather. It was uninhabited and was visited only by the few fishermen and whalers who happened to pass that way, until the opening of the feather trade in the 1880's made living there economically desirable.

The island has been known to the Japanese since about 1700. The coastal whalers and fishermen who passed by it in those early days apparently bothered the swarms of birds very little. However, old Tokugawa legends say that the whalers occasionally brought albatrosses into Edo City (now Tokyo), where the meat was sold under the name of "Okino-tsuru" (off-shore crane) or "Nadano-tsuru" (rough-sea crane). The first settlement of the island was made by about 50 Japanese who arrived there in November, 1887, to collect feathers. They killed albatrosses steadily each year throughout the breeding season from October to May, and when not so engaged, eked out their living with a little desultory farming and fishing.

The first authentic account of the island was written by a Japanese named Toru Hattori, about whom biographical details are lacking.

Although not primarily an ornithologist (this is his only known paper), he was obviously an educated man and something of a scientist. Hattori made a 2-year survey trip, apparently for the Japanese Government, through the Izu and Bonin Islands, during which he spent more than 100 days from April to July, 1889, on Torishima. Soon after his return to Tokyo he wrote and published in the *Zoological Magazine* (Hattori, 1889) what still remains the best available description of the island's bird colony. His account is worth quoting in some detail, for it furnishes many hitherto unknown facts about Steller's Albatross:

Though the island lacks drinking water, it has hot springs and good earth, but no trees. Instead, the whole island is covered everywhere by thick reeds, or "Mukasa" in the local Hachijo dialect, which provide good resorts for the albatrosses. There are three or four large concentrations of the birds, which are called "Torihara" or "Torippara" [literally "bird field"]. The largest one, which is on top of the island, covers almost 25 acres and is covered with innumerable birds. The people call it the "Umi gachobara" [sea goose field]. The other concentrations are smaller, covering from 7 to 12 acres each. At a distance the albatrosses on them might be mistaken for fallen snow. When they fly up in the sky, they resemble a swarm of mosquitoes and they float in the air like white breaking waves, truly a sight more than wonderful!

... The two species of albatrosses here, which both belong to the genus *Diomedea*, are known locally as the "Shirabu" [white pattern] and "Kurobu" [black pattern] from the color of their plumage, but they are often confused. The one commonest on our island is the "Shirabu," which . . . is very rich in fat, each bird yielding over a pint. They are especially fatty from September to November, but lose much of it during the period of feeding the young. The feathers smell badly, but not as badly as the meat . . .

We experienced here some most astonishing and intolerable things, particularly the peculiar smell which enveloped us continually, the birds' cries which continued without ceasing throughout the night, and a kind of tick which attacked us freely. We became accustomed to the smell in a few days, but the never-ceasing night cries

<sup>3</sup> Lat. 30° 29' N, Long. 140° 19' E; also called Ponafidin or St. Peters Island.



broke our sleep and assaulted our ears from all sides, even above the pounding of the sea. The ticks roamed everywhere on the island. . . . When we arose from our beds in the morning, we found them on the floor filled with our blood from their night feeding. They particularly attacked our feet, causing them to swell greatly. They also appeared to attack the bird's feet to suck blood. The birds also have a kind of feather louse and a few other external parasites, one of which is a small beetle which has a very offensive smell and also attacks man.

. . . The albatrosses fly in large flocks 10 or 12 miles from the island, but are more numerous within 5 to 8 miles. They are most plentiful on the sea on fine, calm days. Few are seen during rough weather . . .

When suddenly alarmed, a bird which has come back from the sea vomits an evil smelling substance, which on examination proved to be a kind of shrimp. None of them was complete enough, however, for myself or even the fishermen to determine the species. The next food in abundance was a squid (*Ommastrephes sloani pacificus*), most familiar to us in Honshu. At times half digested miscellaneous fish meat and bones were found, and occasionally quite a large fish is vomited. The fact that all these foods are plentiful in the vicinity probably makes the island particularly attractive to the albatrosses.

They begin to appear on the island in September and by the latter part of October they cover the whole island. From where they come, where they copulate, or which is the male and which the female are hard to tell. The black colored young birds do not come back after they have left the island, but the smaller individuals with the black spotted plumage which appear the following autumn may be one-year-old birds.

In September and October they build concave nests of earth, about two feet in diameter. The site selected is an open place, with low, soft grasses, the reed fields being avoided. Each bird lays only a single egg, about  $6\frac{1}{2}$  inches long and  $2\frac{3}{4}$  inches thick. The shell is white and thin, very fragile and very smelly. The contents are less albuminous than a hen's egg, and not as good eating. The incubation is done very faithfully, the birds not taking any food during it. At the approach of men, they only clack their bills with anger but never leave the nest. We could not make them quit their nests

even by lighting a fire in the nearby grasses and they remained even though their plumage took fire.

The hatching period begins in January. When born the chicks are covered with pale black down, thinner on the head, and with black feet and bills. The parents now become very busy, carrying food in their crops from the nearby waters. They feed the young, bill to bill, with a yellow, bad smelling liquid. During this vomiting operation the parent appears to be in great agony, but the structure of their bills is well adapted for this method of feeding. Whether this liquid is a nourishing substance produced in the bird's crop, or nothing but rotten fish juice is not clear. The young birds vomit this yellow substance when frightened.

The death rate of the chicks is high, the main causes being starvation after losing their parents, death from parasitic insects, and, worst of all, the attacks of crows, which are very abundant on the island. Two or three crows will attack a chick, picking at its hip until they kill it, and then devour it. Almost one-third of the chicks perish from these causes. Not only the chicks but also well-fledged young birds and even adults often die, being unable to fly out of bushy places where they alight. We found the carcasses and bones of many such birds scattered over the island.

By early June young birds are grown almost to adult size. The head is the last to acquire true feathers. They are fed by the adults until the parents leave the island in the middle or end of June. Then the young birds begin to leave the island, taking advantage of favorable winds, most often during the night when the sea is calm. Early mornings during this period the black young birds cover nearly the whole sea surface near the island. They remain and feed freely near the shore for the first week or so. But after the first windy night with rough seas, you will not find a single bird remaining the next morning. Thus the whole island is entirely cleaned out of albatrosses by mid-July.

The so-called "doyonami" [mid-summer big waves], which visit the Pacific coast of Honshu at this season, are often accompanied by many young black albatrosses, which are frequently mistaken for the other species, the "Kurobu." This latter bird is smaller than the foregoing. It is more gentle by nature and never mixes with the "Shirabu" colony but nests and rears its young near the shore. Its breeding season is later than the "Shirabu". . . .



The feathers are sold as a substitute for cotton, or for ornamental use. Its fat is used for food and manufacturing, and the dried meat makes fertilizer. Forty men and women came here and began to slaughter albatrosses last year. To catch the birds, they approach them in parties of four to prevent the bird from flying up. They can only run with outstretched wings until they come to a slope or get a favorable gust of wind; so they are chased upward from below. Thus the birds in the reeds have to be surrounded, but the incubating birds are very easily approached. They are killed by striking them on the head with a club, and it is not difficult for a man to kill between 100 and 200 birds daily.

When I left the island in July, the decrease of birds was not yet perceptible. Likewise, they were as tame as they were early in the season. After staying on this unique southern island with the albatrosses as my friends, I have felt an intimate feeling of attachment for them, with which feeling I have written this paper.

The Japanese settlement on Torishima, which gained its living almost entirely by killing albatrosses, increased steadily as the feather trade continued to grow through the 1890's, and by 1900 it boasted a population of at least 300. The immensity of their scale of operations is suggested by the hand-railway they built to carry feathers from the top of the island to the shore, where a cableway to the roadstead in Chitose Bay facilitated loading the spoils. Yamashina (1942: 244) estimates that they had slaughtered at least 5,000,000 albatrosses by August, 1903, when the island's volcano erupted and stopped the feather gathering temporarily by killing all the Japanese inhabitants. As the eruption occurred during the non-breeding season (of the albatrosses) its only effect on the birds was to destroy part of the former nesting territory.

Very little information is available about conditions on Torishima between 1903 and 1930. The Japanese resettled the island a few years after the eruption, and began their feather harvesting again, but nothing further was written about the island and its birds until Viscount Yamashina landed there on February 15, 1930. He was able to spend only a few hours on the

island, but after returning to Tokyo he wrote (1931: 5-10):

Torishima is no longer as it used to be, although it is probably still the most important breeding place of this bird. . . .

When we climbed to the top of the crater wall we saw a *Haliaetus pelagicus* fly away. The flat bottom of the huge crater, 350 yards wide and 900 yards long, was filled with damp spots or pools caused by the rain. Here we found about 20 Steller's Albatrosses, which, according to the villagers accompanying us, are unable to fly out from the bottom of the crater and remain there to become the victims, one by one, of the eagle we saw.

The top of the crater wall was pebbly. At the east end of it we found a colony of about 400 *Diomedea albatrus*. No unhatched eggs remained but we found about 30 chicks, grown to the size of a cat. . . . Walking further along the edge of the crater we found a sandy plain extending from the east end, one corner of which was occupied by about 1,000 Steller's Albatrosses. This constitutes the main breeding colony on the island. Even taking into consideration the eggs stolen by the natives, we get some idea of the low rate of reproduction of this species from the fact there were less than 100 chicks among the birds.

The south side of the crater wall was covered with reeds, but in bare spots here and there we found smaller colonies from 20 to 100 birds each. In one of these I saw with my own eyes the terrific slaughter which I could hardly bear to witness. Only the word "slaughter" can express the sight. This called to my mind the paragraph in Hornaday's "The Tragedy of the Laysan Albatross" (p. 242). "Schlemmer, the slaughterer, bought a cheap vessel, hired 23 phlegmatic and cold-blooded Japanese laborers and organized a raid on Laysan." I hope to prevent any further such unpleasant occurrences in Japan.

Yamashina was as good as his word, and, largely as a result of his efforts, Torishima was declared a "Kinryoku" (no hunting area) in 1933 for a period of 10 years. We will never know whether this designation would have saved the colony, for the inhabitants of the island, in anticipation of the impending legislation, wiped out the birds before official word of

it could reach them. Unable to return in person, Yamashina had sent his assistant, Mr. Nobuo Yamada, there in 1932 and 1933 to observe conditions for him. Yamashina writes of those last days as follows (1942: 244):

On this remote island the policy of protecting the albatross was not strong enough to prevent the collecting of their feathers, which continued undiminished. When I visited the island in February 1929 there were only about 2,000 albatrosses there. When Yamada went there in April 1932, he observed only a few hundred. On his visit in April 1933, he counted less than 100. This may have been partly the result of pasturing cattle on the breeding grounds after 1932, but the fatal cause was the last great massacre perpetrated by the inhabitants in December 1932. None of the inhabitants ever refer to this slaughter but attribute the disappearance of birds to a storm in November 1932. But Mr. Fujisawa, the elementary school-teacher on the island, told Yamada in April 1933 that in December 1932 and January 1933 over 3,000 albatrosses were killed. This last great slaughter was undoubtedly perpetrated by the inhabitants in anticipation of the island's soon becoming a bird sanctuary.

To determine the status of the species at sea, Yamashina asked the Japanese Marine Laboratories and the boats of the Yaizu Fishing Company to collect albatrosses for him on the open ocean between 1933 and 1936. He noted (1942: 248) that the only Steller's Albatross they found was an immature bird taken near Morell, Hawaii, on February 28, 1936. On recent examination of this specimen, however, it proves to be a mature *Diomedea nigripes*.

Torishima also had small colonies of Black-footed and Laysan Albatrosses. According to Yamashina the Black-footed Albatross was always far less numerous on the island than Steller's. He states (1942: 246), "It owes its survival until recent years to the relative unattractiveness of its plumage, and to its nesting sites, which were on the grassy spots on the inaccessible cliffs on the island. Yamada found a colony of about 200 in April 1932, but could find only a few birds in April 1933." Concerning

the Laysan Albatross, the same authority (loc. cit.) says, "This species seems to have become a resident of Torishima comparatively recently. The inhabitants told me in 1930 that it first appeared on the island about a dozen years previously. In 1930, the population reached 50, but had decreased to only a couple of birds in 1933."

During Yamada's visit to Torishima in 1932 he banded 22 Steller's Albatrosses on April 9. Eleven of these birds were reported to the Tokyo Government from the same place in November, 1932, and five more on June 30, 1933. Although no details are available, it is assumed these returns were from birds killed by the inhabitants. This is the last unquestionable evidence we have of Steller's Albatross existing in the flesh.

Whether any Steller's Albatrosses ever returned to Torishima after 1933 is not known. If they did, and were not slaughtered by the settlers, who then had to turn from feathers to fish for their livelihood, the island was soon to be made even more untenable for them by another catastrophe. The volcano erupted again in 1939, even more violently than in 1903. The inhabitants were able to escape, but extensive flows buried the birds' former breeding grounds under 30 to 100 feet of fresh lava making them uninhabitable for any albatross which might have survived the massacre.

The main crater overflowed again in 1941. One river of lava flowed down over the cliff into Chitose Bay, the little cove on the north-west corner, which was formerly the island's only anchorage and which gave protection in the old days to the ships as they loaded feathers. This flow filled the little cove completely and the partly sheltered landing place it once afforded is now a forbidding, jagged rampart of black, volcanic rock. Thus Torishima is now more difficult of access than ever before. Except in the calmest weather, the perpetual ocean swells break entirely around its unbroken shore line, regardless of the wind direction.

During World War II, the Japanese maintained on the island an observation and aircraft



warning outpost which was removed immediately after the surrender. The small garrison left behind a legacy of several pairs of house cats, which, at last report, were still managing to survive but were "very wild."

In 1946, at the request of Occupation authorities, the Japanese Government established on Torishima a meteorological observatory, manned by 14 men. It is a lonely and unpopular post, to which supplies and relief personnel are brought by vessel only once every 6 months. Frequently the supply ship has to heave-to off shore and wait for days for the weather to abate sufficiently to allow a landing to be made. Technicians of this weather station report they have observed no albatrosses on the island since their arrival in 1946. However, they state that the slopes now teem with Fork-tailed Petrels (*Oceanodroma markhami owstoni*), millions of which breed in holes under the lava. As is normal with petrels, these birds come to the island only after dark. The weather station personnel, noting the birds' tendency to fly to a bright light at night, tell how delicious meals of roast bird can be obtained simply by building a big bonfire after dark and letting the petrels fly into it of their own accord.

I have tried to visit Torishima to look for Steller's Albatross and to judge conditions there for myself ever since my arrival in Japan 3 years ago. However, available transportation never coincided with freedom from other duties during the breeding season until the spring of 1949, when I was able to accompany a whaling catcher on a short trip to the Bonin Island whaling grounds. On our voyage out we passed Torishima after dark. On our return on April 9, however, we reached the south side of the island in mid-morning. But the weather was so rough that the high seas breaking all around the island's 7½-mile perimeter made landing out of the question. Our schedule did not allow us to wait for the wind to abate, so I had to be content with making what observations were possible as we sailed around the island just outside the line of breakers several hundred

yards off shore. These observations were sufficient, however, to verify the verbal reports of the weather station personnel that no albatrosses are present on the island.

The only part of Torishima not affected by the recent volcanic activity is the steep northwest slopes where the low buildings occupied by the weather station staff are huddled. Elsewhere, except on the forbidding vertical cliffs, the entire surface of the island is now covered with stark, lifeless, black-gray lava. Where the flow thins out on the northwest slopes, a few dead, white sticks are mute remnants of the brush growth that formerly covered the island. Also on these slopes some sparse grassy vegetation is visible, but there is no sign of those thick reeds, or "makusa," which formerly sheltered the albatross colonies. The main crater is still smoking and fumes issue from cracks and fissures all over the summit of the island.

We saw no albatrosses whatever on or near the island, and very few other birds. On the sheer southern cliffs a few spots of white guano betrayed the scattered roosts of lonesome cormorants. A few solitary gulls scavenged over the surf along the shore. Otherwise, for all we could see, the island was birdless. It will probably be many years before Black-footed and Laysan Albatrosses are able to establish themselves there again, and its once fabulous colony of Steller's Albatrosses may be considered to have vanished forever.

#### BONIN ISLANDS

Next to Torishima, the best-known colonies of Steller's Albatross were those in the Bonin Islands. Here, it will be remembered, most if not all the eggs in western collections were taken. Apparently these colonies were never as large as the Torishima rookery, or if they were, they had dwindled markedly from the attentions of the feather hunters before any accounts of them were written. The first mention in Japanese literature of Steller's Albatross in the Bonins is S. Yoshiwara's statement (1901: 310) that "Albatrosses are reported as comparatively rare

in the Bonins, but I heard that some come regularly to the Muko-jima Islands. However, it is impossible to hunt them there for feather gathering."

The species may have bred on other of the Bonin Islands, but there is definite evidence for its having nested on only two of them. The first of these is Kita-no-shima, the northernmost islet of the Parry Group,<sup>4</sup> where five eggs in the Yamashina collection were taken in February, 1928. Toku-Taru Momiyama, who spent most of 1924 and 1925 collecting birds in the Bonins, has four eggs from Kita-no-shima given him by local fishermen, three of them taken in early November, 1922, and the other on November 23, 1924. Momiyama was never able to land on this islet during his stay in the Bonins, being prevented from doing so by rough seas every time he tried. He informs me, however, that when he sailed close to it in 1924, he saw only about 30 adult birds on its slopes. Kita-no-shima was designated by the Japanese Government as a "no hunting area" in April, 1926, but the protection, as in all other cases, was never effective, for itinerant fishermen in the neighborhood apparently continued to raid it at will.

The Bonin fishermen also gave Momiyama an egg taken December 1, 1924, and an adult bird taken October 20, 1924, on Nishi-no-shima.<sup>5</sup> Momiyama landed on this isolated islet in April, 1925, but he tells me there were no eggs or young in evidence, and the fishermen with him clubbed the five or six albatrosses they found there the moment they got ashore, before he could stop them, and before he could make any observations.

Kobayashi and Ishizawa (1942: 33) state that the bird bred also on Yome-shima and Muko-shima Islands.<sup>6</sup> No specimen evidence exists to back this claim, and Momiyama recalls

seeing no birds on either island during his stay there. However, H. Okabe (1930: 272) gives the following information by one of the residents of Muko-shima, a certain Mr. Iwasaki:

Two kinds of albatrosses, black ones and white ones, occur on the island. The white one comes in late October, the black one in mid-November. The white one weighs about 7.5 kilograms, the black ones about 5.6 kilograms. The date of egg laying is uncertain, but the egg of the white one weighs 375 grams, that of the black one from 260-300 grams. The white bird builds its nest up in a cone about 15 centimeters high, but the black one only gathers a few dried grasses together to lay its eggs on. The hatching time varies, but I think incubation takes about 7 weeks. The adult birds leave the island in May, and the young leave in June.

I spent several days in late March and early April, 1949, on a whaling catcher boat operating in the vicinity of the northern Bonins. During this time I was able to inspect closely every one of the islands in the group, though the seas were so rough and the winds so high during the entire period that I was able to land only on Muko-shima. We cruised for two days in the Parry Group, sailing around all its islets as closely as possible. With the exception of Muko-shima, all these islands are so small that their entire area is visible from the sea. These islands are now uninhabited, but during World War II, Muko-shima was occupied by a small garrison of about two or three hundred Japanese troops. When the troops were evacuated after the surrender, their barracks were razed, but evidences of occupation still remain in the form of the cement foundations of the barracks, old anti-aircraft gun-pits and machine-gun nests enfilading the possible landing places. The most deplorable evidence of the recent Japanese occupation is the scarcity of bird life on the island. Two endemic Bonin Island land birds, *Zosterops palpebrosa alani* and *Apalopteron familiare familiare*, were formerly abundant on Muko-shima. I hunted for them assiduously during my 4 hours on the island, but could find no trace of either species. They were undoubt-

<sup>4</sup> Muko-jima Retto of the Japanese; Kita-no-shima is located at 27° 43' N, 142° 06' E.

<sup>5</sup> This islet was formerly known as Rosario Island and lies in 27° 15' N, 140° 53' E, about 80 miles southwest of the Parry Group.

<sup>6</sup> These are larger islands of the Parry Group. Muko-shima is 3 miles, and Yome-shima 15 miles, south of Kita-no-shima.



edly wiped out by the Japanese garrison who probably caught them in mist-nets for food. The only birds on the island were a few scattered pairs of Red-bellied Rock-Thrushes, a wide-ranging species which has undoubtedly returned there since the departure of the Japanese. No albatrosses of any species breed today in the Parry Group.

We spent one day sailing around Nishi-shima, but again were unable to land because of the rough seas. This low island is only about 700 feet long and the seas were so rough and the winds so high that spray was blowing completely over it. I saw large flocks of Salvin's Shearwaters, a few Bulwer's Petrels, Black-footed and Laysan Albatrosses, and a single Spectacled Tern feeding in the tide rips just north of the island. It was obvious, however, that no albatrosses now breed on Nishi-shima.

#### PESCADORES AND SOUTHERN RYUKYUS

We know from the observations of La Touche (1895), Seeböhm, and other early writers that Steller's Albatross was a common winter bird in the waters from China to Formosa and the Ryukyus. But the statements in the *Hand-List of Japanese Birds* (1932 and 1942) that the species breeds in the Pescadores Islands, on Agincourt Island off the northern coast of Formosa, and on Kobisho Island in the southern Ryukyus are backed by indisputable specimen evidence only for the latter locality.

The earliest reference to Steller's Albatross on Kobisho<sup>7</sup> is Kuroda's (1925: 148) remark that "Dr. Tsuneto told me that the bird was very abundant on Kobisho in Senkaku Retto and also on Rasa Island." Kuroda notes that no specimens have been taken at either locality, and makes no mention of the species' breeding. Kobayashi (1930: 371) states, however, "One egg, 118.0 x 77.5 millimeters, of *Diomedea albatrus* from Kobashima [Kobisho], Senkaku Retto, was given me by Mr. Takuya Iwasaki."

The former occurrence of a breeding colony on Agincourt Island,<sup>8</sup> while probable, lacks specimen substantiation. Dr. Kuroda tells me a picture of the rookery on this island, showing clearly identifiable adults and young birds, was published in a brochure on Formosa issued by the Japanese Government of Taiwan about 1895. His copy was lost when his library was destroyed in 1945, and a search through other Tokyo libraries has failed to unearth a duplicate. The only other mention of the species on Agincourt is in the memoirs of Kaju Enomoto, a civil servant formerly employed by the Ministry of Agriculture and Commerce. Enomoto writes (1936: 29) that on April 28, 1901

I saw Agincourt Island far on the horizon, but our ship did not approach within 4 miles of it, so I could not identify any of the birds on the island. The Captain, who was an experienced man in those waters, told me "Numerous albatrosses live on this island, but you can't find many of them now because it is not the breeding season."

The same Enomoto is apparently the only authority for the statement that Steller's Albatross bred in the Pescadores. In the continuation of his memoirs (1937: 8) he relates

I once stayed in the Pescadores for about one year when birds were still plentiful. During my stay I had the chance to observe albatrosses. While my observations may not be satisfactory, I regard them as valuable because wild birds have decreased so tremendously in recent Japan, and you can observe albatrosses now in Japan only on far-away Torishima.

It was the last of February in 1902 when I saw the most albatrosses. The weather being calm, I had an opportunity to make a trip on the patrol ship of the local Pescadores government. During the voyage I saw albatrosses crowding on Byo-sho.<sup>9</sup> The hatching season was almost over, and it was the season when the parent birds do not stay on land in the daytime. Nevertheless numerous birds were seen, and I was delighted with the opportunity. But as the

<sup>7</sup> Lat. 25° 56' N, Long. 123° 42' E, the northernmost island in the Senkaku Archipelago, a little group of islets about 250 miles southwest of Okinawa and 100 miles northwest of Formosa.

<sup>8</sup> Hoka-sho of the Japanese, 25° 38' N, 122° 04' E, about 45 miles due north of Formosa.

<sup>9</sup> A small islet in the extreme southwest of the Pescadores group, 23° 19' N, 119° 8' E. [Author's note.]

government officers had no business on this uninhabited island, the ship did not stay long, and I could not land on the island to collect eggs and chicks. It was hard enough to get specimens of adults.

It is also likely that the species may once have nested on other isolated islands south of Japan, from which it was extirpated before authentic record could be made of its presence. Certainly it should have bred on one or more of the Daito Islands<sup>10</sup> where Kuroda (loc. cit.) was told it was "very abundant on Rasa Island."

#### THE FEATHER TRADE

The decline and probable extermination of Steller's Albatross were caused entirely by human persecution on its breeding grounds, which started about 1885 when the value of its feathers was first realized. The white body feathers of Steller's Albatross were particularly valued by the plume hunters, because they brought the top prices when marketed as "swansdown" for quilts and pillow stuffing. The wing and tail feathers were sold as "eagle feathers" for quill pens, and for millinery and other ornamental purposes. Each albatross yielded about  $\frac{1}{4}$  pound of feathers, worth in those days about 5 sen per pound. This seems little enough, but harvesting them was a profitable business because the birds were so plentiful and labor so cheap.

The revolting details of the nefarious feather trade never have been and probably never will be written in full. It was conducted mostly by illiterate hunters and fishermen and was supervised in its hey-day by close-mouthed business interests concerned only with immediate profits. The first feather hunting was done by casual fishermen, but as the trade proved more and more remunerative, it was taken over by big business. Most of the Japanese feather hunting was supervised by the South Seas Trading Company, which is now defunct. Its records of the feather trade, if they ever existed, and the men connected with it are no longer traceable.

The trade was abolished by law in America 50 years ago, but not before our egrets and terns were almost wiped out. Protection reached the Hawaiian archipelago just in time to save the famous Laysan colonies, to which the plume hunters were then turning their attention. Yamashina states (1942: 244) that the Japanese Government prohibited the killing of albatrosses in 1907, but the statutes show them to have been legal game birds until the amendments of 1947, and the *Annual Hunting Statistics* published by the Ministry of Agriculture list from 500 to 4,000 "albatrosses" killed each year from 1930 to 1942, the last year for which figures are available. These data, however, are neither accurate nor specific, and undoubtedly refer to the other two species of North Pacific albatrosses. The only protection ever afforded Steller's Albatross by the Japanese was their designation of Torishima and Kita-no-shima as "no hunting areas," and apparently they made no effort to enforce the law on these outlying islands. In both cases the designation was for a 10-year period only, which was not renewed at its expiration.

Japan has never had a law prohibiting traffic in or possession of protected birds or parts thereof, and the import-export trade in feathers flourished in Yokohama as long as birds were available to supply the demand. The accompanying graph shows, from the only figures available, the total exports of feathers from Japan. All sorts of wild birds contributed to this total, which is impossible to break down by species, but feathers from the Pacific sea bird colonies constituted the major portion, and Steller's Albatross, as long as it survived, was one of the most sought sources of supply. Although we hear little about it nowadays, the trade has not died out entirely. A demand for feathers of all sorts still exists, Paris being the main market, but the export center is reported to have shifted some years ago from Japan to Shanghai, China.

#### VALEDICTUM

We are loath to regard any species as extinct

<sup>10</sup> Lat. 24° 28' N, Long. 131° 11' E, midway between the Bonins and the Ryukyus.



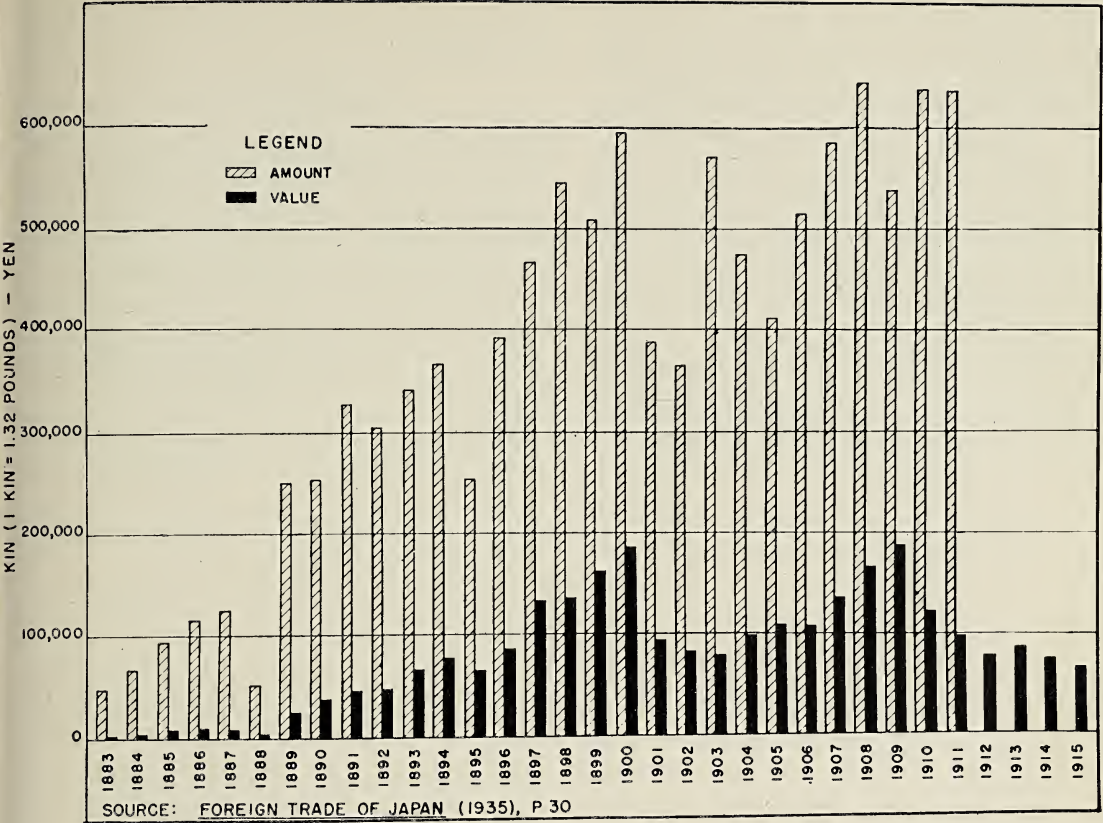


FIG. 1. Export of feathers from Japan.

until every possibility of its survival has been investigated and exhausted. Even then the negative evidence is unsatisfactory, and the hope always remains that in some overlooked corner of the globe the species will once more be found, even as *Notornis* was so recently re-discovered in the mountain fastnesses of South Island, New Zealand.

It is to be noted that Steller's Albatross has been reported several times since 1933, most recently in 1944 and 1945, as having been seen at sea in Alaskan and Aleutian waters on the species' summering grounds. As the species is reputedly a shy bird which seldom follows or comes close to ships, it is difficult to observe except on or near its breeding grounds, and it must be remembered that the species may be confused easily at a distance with the other two North Pacific albatrosses. Adults resemble the

Laysan Albatross, but lack its black back; immatures resemble the Black-footed Albatross, but have a flesh-colored instead of a black bill. Hence, sight records made at sea, even by the most careful and reliable observers, must be regarded as doubtful unless amply substantiated.

As mentioned previously, in March and April, 1949, I cruised for 10 days in the southern Izu and the northern Bonin Islands, the best known former breeding grounds of Steller's Albatross. In its normal life cycle we know that this species did not leave the breeding grounds until late May and June, so at the time of my visit any surviving individuals should have been in the vicinity attending their fairly well grown young. I was able to sail within close inspecting distance of every island in this chain on which Steller's Albatross is known to have bred. I also visited every other island in the area which

could possibly support a breeding colony of birds. Needless to say, I studied carefully every albatross that came within sight during the entire trip. If Steller's Albatross were still breeding in this area, I should have seen some sign of it, either on the islands or on the seas nearby. There was no scarcity of Black-footed and Laysan Albatrosses at sea in this area, both seeming to occur in normal numbers, although the Black-footed outnumbered the Laysan about fifteen to one. Despite the most careful watch, I saw no albatrosses close to or on any of the islands, and no sign whatever of any bird that could conceivably be construed as Steller's Albatross during the entire voyage.

The chances that any of these fine birds remain alive today are remote indeed, unless they be a few old individuals perhaps beyond the breeding age, which spend all their time at sea and never come to the breeding islands. Although their known former rookeries are all small isolated islands far off the beaten tracks of commerce, and extremely difficult of access, the waters surrounding them have swarmed with Japanese, Chinese, and Okinawan fishermen for the last 50 years, except for a brief period late in and immediately after World War II. No person interested in birds or able to differentiate between the three North Pacific albatrosses has visited any of the known breeding grounds of Steller's Albatross in the southern Ryukyus and off Formosa. But it is hard to believe that any islet exists in this area which has not been visited many times by Oriental fishing boats in the 16 years since the last known Steller's Albatross was killed. It is equally unlikely that any of these craft would pass by an out-of-the-way island with a bird on it without its crew attempting to land and kill the bird. Policing these islands to prevent such depredations is well nigh impossible, both politically and economically. Although there is always the possibility that a few pairs may remain on some isolated, as yet unvisited islet, it seems only too likely that Steller's Albatross has become one of

the more recent victims of man's thoughtlessness and greed.

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## A Second Hawaiian Species of *Alectryon* (Sapindaceae): Hawaiian Plant Studies 17<sup>1</sup>

HAROLD ST. JOHN<sup>2</sup> AND LAFAYETTE FREDERICK

THE GENUS *Alectryon* has been known in the Hawaiian Islands by a single species, *A. macrococcus* Radlk. It was first collected by Hillebrand, but, though he found it on two different islands, Molokai and Oahu, he never succeeded in assembling complete material. The binomial was published in 1890, based solely on Hillebrand's incomplete collections and data. Since that time, successive botanists, Rock, Forbes, Degener, and others, have found new localities for the species; it is now known on Kauai, Oahu, Molokai, and Maui. Nevertheless, *Alectryon* is still considered a rare tree. On Kauai it was discovered by Gay, and by Lydgate in Olokele Valley, apparently early in the 20th century, but it has not been found there since. On Molokai it is apparently extinct at the type locality, though Degener found another station only a mile or two away at Puu Makaliilii, where in 1928 there were two dying trees. On Maui it was known from the rich, dry forest at Auahi on Haleakala, where Rock in 1910 found 40 trees. Since Rock's time this rich area has been deforested by cattle grazing. Another station was found by Forbes in Olowalu Valley, west Maui, in 1920, but no one has found *Alectryon* there since. On Oahu it is now known to extend, in the Waianae Mountains, from Pahole Gulch to Ekahanui Gulch, or nearly the full

length of that mountain range. Yet, even on Oahu, the trees are few and remote and the discovery of one is a noteworthy event on a day's exploration. Most unusual is the large single or double fruit with its woody pericarp and abundant, juicy, scarlet, edible aril, somewhat resembling those of the related "litchi."

It is now evident that the genus contains more than one Hawaiian species and that the original *Alectryon macrococcus* was described from material assembled from two islands and representing two species. To straighten out this confusion it has been necessary to select a lectotype for the older species and describe the other as a new species.

### SAPINDACEAE

*Alectryon* (§Mahoe) Mahoe St. John & Frederick, sp. nov.

Figs. 1, 2.

*Diagnosis Typi:* Arbor 7 m. alta, ramis fuscis rubri-brunneis, glabris, cicatricibus 4.5–6 mm. latis scutiformibus pallide brunneis fasciculis 3, ramulis foliosis 4–6 mm. diametro terebibus adpressi-puberulis, internodis 5–35 mm. longis, foliis 27–42 cm. longis pari-pinnatis, petiolis 6–12 cm. longis adpressi-puberulis, foliolis 2–3-jugis, petiolulis 8–15 mm. longis basi inflata adpressi-puberulis, foliolis 10.5–21 cm. longis 5–10 cm. latis, plerumque ellipticis vel minime lanceo- vel oblanceo-ellipticis rare ovalibus plerumque plusminusve asymmetricis, apice obtusi, basi rotundata vel abrupte subcuneata, laminis rigide crasse chartaceis fuscis-viridibus glabris margine integri plani vel undulati, infra pagina intervallis glabris nervis salientibus adpressi-puberulentis, venulis saliente reticulatis,

<sup>1</sup> This is the seventeenth of a series of papers designed to present descriptions, revisions, and records of Hawaiian plants. The preceding papers have been published in *Bernice P. Bishop Mus., Occas. Papers* 10(4), 1933; 10(12), 1934; 11(14), 1935; 12(8), 1936; 14(8), 1938; 15(1), 1939; 15(2), 1939; 15(22), 1940; 15(28), 1940; 17(12), 1943; *Calif. Acad. Sci., Proc.* IV, 25(16), 1946; *Torrey Bot. Club, Bul.* 72: 22–30, 1945; *Lloydia* 7: 265–274, 1944; *Pacific Sci.* 1: 5–20, 1947; *Brittonia* 6(4): 431–449, 1949; *Gray Herb. Contrib.* 165: 39–42, pl. 3, 1947.

<sup>2</sup> Chairman, Department of Botany, University of Hawaii. Manuscript received June 28, 1948.



venis lateralibus principalibus alternatis uno latere 10–12 arcuati-adscententibus angulo  $120^{\circ}$ – $145^{\circ}$  apicibus venarum juxta margine arcuati-connatis, inflorescentibus axillaribus 9–30 cm. longis, 6–16 cm. latis adpressi-puberulentis, pedunculis 0–52 mm. longis, paniculis conicis, pedicellis 0.5–3 mm. longis, bracteis 1–2 mm. longis subulatis caduceis; floribus evidenter polygamis, specimina typica solo cum floribus hermaphroditis, calycibus 2 mm. altis 2–2.5 mm. diametro valvatis patelliformibus basi truncata dense adpressi-sericeo-puberulentis, lobis 5 inaequalibus anguste deltoideis loba maxima tubam subaequantibus, petalis nullis, staminibus 6–8 intra disci marginem circa pistillum insertis, filamentis 0.4 mm. longis subulatis puberulis, antheris 1.1–1.3 mm. longis elliptici-oblongis 4-locularibus 4-lobatis rubescentibus vel flavescentibus, pistillo 2-loculare basi urceolata e latere evidente compressi exserti dense breve sericeo, stylo gracile circa 0.5 mm. longo, stigmatibus 2 liguliformibus 1 mm. longis rectis deinde recurvatis, fructibus tarde irregulariter diruptis, loculis fructicis 1–2, specimina typica cum fruticibus 1-locularibus 25–38 mm. longis subglobosis laevibus fuscis-brunneis, pericarpio duro lignoso pallido in basi 5 mm. crassa in apice 3 mm. crassa, arillo carnosio in stato post-maturo contracto et in apice seminis coronato, semine uno 19 mm. lato 12 mm. alto in apice proximi scutiformi concavi ossei lucide fuscibrunnei, testa lucida coccinea, apice distali rigide spinosi.

*Description of All Specimens Seen:* Tree 7–10.5 m. tall; branches dark reddish-brown, glabrate, in age the bark pale yellowish-brown, black-spotted; leaf scars 3–6 mm. wide, rounded shield-shaped, pale brown, bundle scars 3; leafy branchlets 4–6 mm. in diameter, terete, appressed puberulous; internodes 5–35 mm. long; leaves 23–54 cm. long, even pinnate; petioles 4.5–18 cm. long, appressed puberulous; leaflets in (1-)2-3 pairs; petiolules 8–22 mm. long, swollen at base, appressed puberulous; leaflets 9–26 cm. long, 5–11.7 cm. wide, commonly elliptic or slightly lance- or oblance-



FIG. 1. *Alectryon Mahoe*: older and younger flowers of type, Frederick & Sakimura 185,  $\times 10$ .

elliptic, rarely oval, usually somewhat asymmetric, apex obtuse, base rounded or abruptly subcuneate, blade stiff thick chartaceous, dark green, glabrous, margin entire, plane or undulate, lower surface with intervals glabrous, with rib and veins prominent and appressed puberulent, the veinlets raised reticulate, primary lateral veins alternate, 10–17 on a side, arcuate ascending at  $120^{\circ}$ – $145^{\circ}$ , inarching and connected near the margin; inflorescences axillary, 9–30 cm. long, 6–16 cm. wide, appressed puberulent; peduncle 0–52 mm. long; panicle





5–10 mm. thick, at apex 2–3 mm. thick; aril fleshy, scarlet, edible, "resembling peach in flavor" (*vide* Degener), shrivelling to a crown on the distal end of the single seed; seed 19–30 mm. wide, 9–12 mm. high, at hilum or proximal end shield-shaped, concave, hard and polished, dark brown, the testa scarlet, shiny, the distal end bearing the aril is produced into short spine-like processes.

*Type:* Hawaiian Islands, Oahu: Puu Kanehoa, South Huliwai Gulch, 2,100 ft. elev.; in open forest with *Neraudia* sp., *Fagara semiarticulata*, and *Planchonella* sp.; tree 30 ft. tall, 6 in. in diameter; Aug. 21, 1947, *L. Frederick & K. Sakimura* 185 (fl. fr.) (Bishop Mus.).

*Specimens Examined* (the list of specimens is arranged in geographical order from north to south; abbreviations—b.=bud, fl.=flower, fr.=fruit): Oahu, Waianae Mountains: Makua Valley, southeast corner, on moderately dry forested slope, Sept. 27, 1932, *O. Degener & C. Judd* 9538 (fr.); Mokuleia Trail, alt. 2,100 ft., tree 22 ft. tall, 4 in. in diameter, open forest, July 13, 1947, *L. Frederick* 183 (b.); Mokuleia, near head of right branch of Pahole (Kukuiula) Gulch, moist forest, alt. 550 m., April 12, 1936, *F. R. Fosberg* 13069 (fr.); Mokuleia, left branch, slopes of Kaala, April 26–May 16, 1912, *C. N. Forbes* 1768-O (fr.); Makaleha Valley, west side of, dense forest near stream, first discovery of staminate flowers, July 21, 1935, *O. Degener et al.* 10906 (fl.); Makaleha (or "pali of Kalaupapa, Molokai"—but this a confusion of data), *W. Hillebrand & J. M. Lydgate*; Kamokukui Valley (between Puuiki and Puu Kamaohanui), large forest tree, April 12, 1933, *O. Degener* 9535 (fr.); Mt. Kaala, base of, near end of Schofield Fire-Break Trail, dense wet forest, 4 trees seen up to 35 ft. high, March 13, 1932, *O. Degener et al.* 9537; Puu Kaala, Waianaeuka, wooded gulch, 2,000 ft. alt., tree, Jan. 8, 1933, *H. St. John & J. Dunn* 12920; Puu Kalena valley S. of E. ridge of, moist forest, alt. 750 m., tree 7 m. tall, March 22, 1936, *F. R. Fosberg* 12987 (fr.); Puu Kumakalii, northeast slope of, forest, April 1, 1936,

*O. Degener* 11111; Kanehoa, Honouliuli, el. 700 m., tree, 7 m. in height, steep north slope, Oct. 25, 1927, *C. S. Judd* 66 (fl.); Kanehoa, Oct. 1929, *G. W. Russ* (b. fr.); Ekahanui, rich forest, April 21, 1936, *O. Degener & M. Martinez* 11108 (b.), 11109 (b.); South Fork of Ekahanui Gulch, Puu Kaua, Honouliuli, 2,300 ft. alt., wooded ridge, young tree 4 m.  $\times$  5 cm., Feb. 27, 1938, *H. St. John* 18684 (fr.); Ekahanui Gulch, Fire-Break Trail, Puu Kaua, Honouliuli, 1,760 ft. alt., lower forest remnant, tree 6 m.  $\times$  8 cm., Feb. 29, 1948, *H. St. John* 23356 (fr.).

Waianae Range, without data: *O. Degener* (fr.).

There was also a collection from second gulch E. of Puu Kaupakuhale, N.E. slope of Puu Kaala, Mokuleia, Oct. 23, 1932, *St. John & Fosberg* 12144 (fr.), but this specimen cannot now be located.

The published record (Hosaka, 1937: 224) of this tree from Kipapa Gulch is the only record for the Koolau Range. This rests only on a field observation, as the single large tree was never seen in flowering or fruiting condition.

Although there are numerous collections of this new species, most of them show only fruit or flower. The collection *Frederick & Sakimura* 185 is chosen as the type because it has foliage, numerous flowers, and three good fruits, all taken from a single tree.

The new species, *A. Mahoe*, is being separated from *A. macrococcus* Radlk. which was based on the material collected by Hillebrand and on the description of his probable new genus, *Mahoe*. Hillebrand had made a collection on the "pali of Koolaupapa" [precipice of Kalaupapa], Molokai, consisting of leaves with old fruit of the previous year; and he had another collection, with leaves only, from Makaleha Valley, Oahu. Lacking flowers and complete material, he conservatively put a question mark beside his new generic name and refrained from publishing a specific name. Having only this same incomplete material, Radlkofer gave it a specific



name and placed it in *Alectryon*. His description is very brief, mentioning only that the large, usually 1-celled fruit is 3 cm. in diameter; the leaflets up to 26 cm. in length, 11 cm. wide; and that the hypodermis of the lower leaf surface is distinctive. Though these few characters could have been selected from the lengthy description given by Hillebrand, it is certain that Radlkofer studied the Hillebrand specimens in Berlin, for the Hillebrand sheet with a leaf and old fruiting branches, labeled "Mahoe, pali of Koolaupapa, Molokai," bore the note in Radlkofer's writing, "*Alectryon macrococcus* m. [ihi] Radlk." We now designate this Hillebrand sheet in the Berlin Herbarium as the lectotype of *A. macrococcus* Radlk. It was probably destroyed in the bombing of Berlin in 1943, but Figure 3

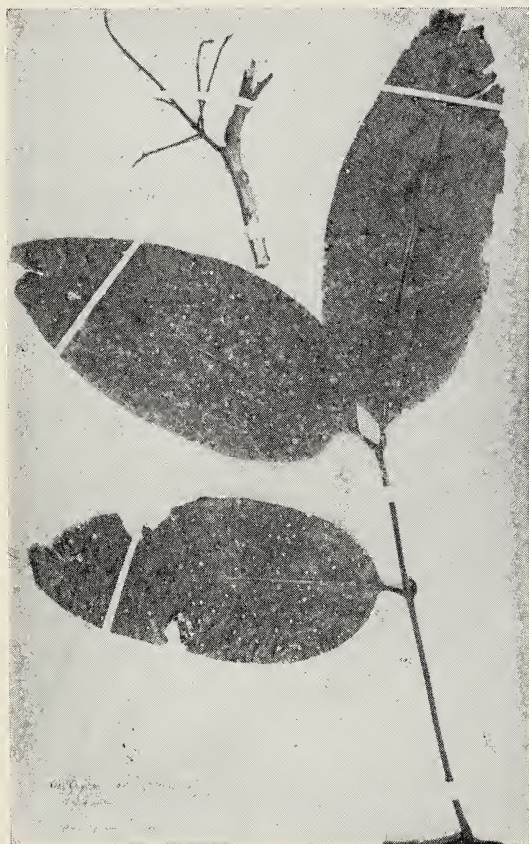


FIG. 3. *Alectryon macrococcus*: photo of lectotype in Berlin Herbarium, "pali of Koolaupapa," Molokai, Hillebrand.



FIG. 4. *Alectryon macrococcus*: flower, Haleakala, Maui, 2,600 ft., J. F. Rock, Nov. 1910,  $\times 10$ .

shows the sheet as it appeared when photographed by St. John in 1935.

*A. macrococcus* Radlk. of Molokai is distinguished by having the leaflets 11–18.5 cm. long, lance-elliptic, densely soft yellowish pilosulous below; perfect flowers with the calyx campanulate (Fig. 4); style scarcely evident; the stigmas short, erect, not diverging. The collections from Maui are very similar and are confirmed as conspecific with the true *A. macrococcus* of Molokai, and they furnish perfect flowers, with anthers only 0.5 mm. long.

In contrast, we find that *A. Mahoe* has the leaflets 9–26 cm. long, commonly elliptic (or slightly lance- or oblance-elliptic, rarely oval), except for the main veins the lower surface glabrous; perfect flowers with the calyx knee-pan-shaped, the base truncate (Fig. 1); anthers 1.1–1.5 mm. long; style slender, evident. These differences seem sufficient to justify the separation of the Oahu plant as a new species. Its specific name is the Hawaiian vernacular one, "mahoe," meaning twins, in allusion to the often twinned fruit.

The illustration by Degener in his *Flora Hawaiensis* of material which he called *A. macrococcus* from Makua, Oahu, is a good representation of fruiting *A. Mahoe*, but his description is a composite of the two Hawaiian species.

There are in the Bishop Museum two sheets of a collection from the island of Kauai: Olokele Valley, J. M. Lydgate, with stems, leaves, and a



single 1-celled fruit. This seems very like *A. Mahoe* of Oahu, but until more complete material is available, it seems unwise to assign it definitely to a species.

Radlkofer in his monograph of the genus (1933: 983) states that the flowers of the genus are falsely polygamous, that is, are male or female, often in the same inflorescence, and that they are falsely stated to be in part perfect. *A. Mahoe* has numerous examples of trees with all perfect flowers, and one example with all staminate flowers, so the generic description should now be altered to allow male, female, or perfect flowers.

A summary of the synonymy of the only other Hawaiian species is as follows:

*Alectryon macrococcus* Radlk., K. Bayer. Akad. Wiss., Math.-Phys. Kl., Sitzber. 20(1): 255, 1890 (as to Molokai plant); *Mahoe* ? sp., Hillebrand, Fl. Haw. Is. 86–87, 1888 (as to Molokai plant); *A. macrococcus* Radlk., Radlk. & Rock, Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry, Bot. Bul. 1: 3–4, pl. 1, 1911 (as to Molokai and Maui plants, the plate being of the Maui plant); Rock, Hawaii Bd. Commrs. Agr. and Forestry, Rept. for 1910: 81, pl. 19, 1911; Rock, Ind. Trees Haw. Is. 277–278, pl. 107–108, 1913 (as to Molokai and Maui plants); Radlkofer, in Engler, Pflanzenreich IV, 165(5): 987–988, 1933 (as to Molokai and Maui plants); Degener, Fl. Haw., fam. 210, text 5/5/37 (as to Molokai and Maui plants; not as to the Oahu plants or the figure based on a plant from Oahu). *Dodonaea* sp., Drake del

Castillo, Ill. Fl. Ins. Mar. Pacif. 6: 144, 1890, in notes under *Dodonaea viscosa*, which is his disposition of *Mahoe* of Hbd.

The generic name was first published in 1788 by Gaertner, with the single species *Alectryon excelsum*, thus indicating that he considered the name to be neuter. Other authors accepted this gender until it was changed to masculine by the monographer Radlkofer (1890: 256). Our present International Rules (Amsterdam) validate this treatment, the choice and adoption of one of the two classic genders, under Art. C.72 (1). The Greek word, *alectruon*, cock, or hen, is masculine or feminine. Gaertner said the fruit was compressed above like a comb—that is, a cock's comb. Hence, Radlkofer, using this indication, adopted the genus as a masculine one, changed the older specific names to masculine, and made all his new specific names masculine. This discussion of the gender is included as various contemporary botanists still retain the generic name as a neuter one.

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- . 1933. Sapindaceae, in Engler, A., *Das Pflanzenreich IV*, 165: 1–1002. Wilhelm Engelmann, Leipzig, 1931–1934. [Part 5, containing the genus *Alectryon*, is dated 1933.]

# The Hawaiian Tun Shells

SPENCER TINKER<sup>1</sup>

## INTRODUCTION

THIS ARTICLE is a brief presentation of information on the Hawaiian tun shell fauna (Doliidae), including synoptic keys, descriptions and illustrations of the different species, and notes on their ecology and distribution.

Included in this paper are two species which the author believes to be previously unknown from the Hawaiian Islands. These species are the spotted tun shell, *Tonna dolium* Linnaeus, and the oil jar or channeled tun shell, *Tonna canaliculata* Linnaeus. No prior records of the occurrence of these species in Hawaiian waters are known. None of the local private collections seen or the several collections in the Bernice P. Bishop Museum and in the United States National Museum included any specimens from Hawaiian waters. It is somewhat astonishing that two species of mollusks of this size should not be represented in any of these Hawaiian collections, some of which are very large and quite complete.

The Doliidae, or tun shells, as the group is often called, is a small group, old and well established, and its members are quite easily recognized by the characters which they present. Of these characters the most significant are the large, light, ventricose shells with spiral ribs and furrows. In distribution the Doliidae is an Indo-Pacific group and all of its species, with the exception of *Tonna perdix* Linnaeus, are found within that area.

## THE HAWAIIAN DOLIID FAUNA

*Species:* The Hawaiian doliid fauna is a small one consisting of but five species which represent about one-fourth of those now known. Of these five species, four are Indo-Pacific in their distribution and one, *Tonna perdix* Lin-

naeus, is circumtropical. The following species are known from the Hawaiian Islands:

*Tonna perdix* Linnaeus, the partridge tun  
*Tonna melanostoma* Jay, the black-lipped tun  
*Tonna dolium* Linnaeus, the spotted tun  
*Tonna canaliculata* Linnaeus, the channeled tun, and  
*Malea pomum* Linnaeus, the apple tun.

*Ecology:* Although the Hawaiian Islands border the Indo-Pacific faunal area and draw the major portion of their shore line fauna from this region, the Indo-Pacific species are not as well represented in Hawaiian waters as in the more centrally located areas of the region. This apparent dearth of species is probably due to the facts that the Hawaiian Islands lie on the extreme northern edge of this region, have a somewhat different ecological picture, and that the shore lines of the Hawaiian Islands have not been adequately explored beyond the depths comfortable for ordinary diving. In Hawaiian waters, at least, the members of this family appear to be uncommon in depths of less than 40 or 50 feet, although occasional specimens of *T. perdix* L. are found in depths of less than 10 feet. At depths beyond 75 feet the number of individuals of *T. perdix* L., *T. dolium* L., and *Malea pomum* L. increases considerably and it is beyond this depth that the two additional new records have been obtained.

Not only does the Hawaiian doliid fauna become more abundant with increasing depth, but it is not uniformly distributed along the shore line: it appears to be more abundant in particular areas. One such area where both species and specimens are especially abundant exists along the southwestern shore of Oahu, and it is from this locality that the two new records were obtained. The reason for the abundance of these species in certain areas is unknown, but it should be noted that the area

<sup>1</sup> Director of the Aquarium, University of Hawaii. Manuscript received December 6, 1948.



mentioned is one in which no well-defined reef exists. It is, moreover, the point on the island of Oahu which is nearest to deep water, the remaining parts of the island shore line being separated from deeper waters by an insular shelf some miles in width.

*Distribution:* The distribution of the species in the Hawaiian Islands is not well known, but it can be said with some degree of assurance that the species previously known from this area are distributed from Hawaii northwestward to Ocean or Kure Islands, inasmuch as specimens are on record from several points along this chain. The range of the two species here newly recorded is unknown and their present scarcity will make their true distribution in the Hawaiian Islands unknown for many years.

### Family DOLIIDAE

Shells large, ovate, thin, hard, with large ventricose body whorls, spirally ribbed, without longitudinal sculpture; aperture very large; spire short and small; umbilicated; anterior canal present, but short; outer lip simple; operculum absent in adult, thin and corneous in young; length, 2 to 9 inches.

The mollusks which inhabit these shells are fascinating to watch for they are large and muscular creatures and active in their habits. The foot is large and fleshy and when expanded is more than twice the diameter of the aperture. The head bears a pair of elongated tentacles which are expanded basally and have eyes near their proximal end. The head bears in addition a long, large, cylindrical, tube-like proboscis which is extensible and very flexible and which ends in a kind of rosette. When undisturbed the mollusk glides rapidly along. The proboscis is held in a forward, slightly raised position forming a gentle S-shaped curve with the free end directed downward, and is waved slowly from side to side.

### Key to the Genera and Species of Hawaiian Doliidae

1. Shells light in weight, thin, hard; outer lip simple; body whorl large; aper-

ture very wide (Genus *Tonna*)..... 2  
Shells heavier; outer lip strongly dentate; body whorl less expanded; aperture considerably reduced, approximately four times as long as wide  
.....*Malea pomum* Linnaeus.

- 2(1). Outer surface of shell marked by a regular recurring color pattern..... 3  
Outer surface of shell variously pigmented without a regular recurring color pattern, blotched and streaked with various shades of black, brown, and yellow ..... 4

- 3(2). Outer lip of shell crenate; outer surface of shell white in color, marked upon the ridges by quadrate brown spots; spiral ridges well developed, approximately as wide as the interspaces.....*Tonna dolium* Linnaeus.

Outer lip without crenations; outer surface of shell brownish in color, usually covered by a network of white lines consisting of regular narrow spiral lines which follow the grooves and which are connected by short, irregular, longitudinal lines crossing the ribs; spiral ribs present, but poorly developed.....  
.....*Tonna perdix* Linnaeus.

- 4(2). Inner and outer lip of aperture marked with black; spiral grooves on outer surface of shell marked with black; ribs on outer surface of shell arched  
.....*Tonna melanostoma* Jay.

Inner and outer lip of aperture not marked with black; spiral grooves on surface not marked with darker lines; ribs on outer surface of shell nearly flat.....*Tonna canaliculata* Linnaeus.

### Genus TONNA Bruennich

Shells large, ovate, thin, hard, with greatly inflated body whorls; surface of shell spirally furrowed and ribbed, without longitudinal sculpture; spire low; aperture large; outer lip simple, with or without crenations; columellar lip broadly expanded; umbilicated, open or closed; operculum absent in adult, present in young.

This genus includes about 21 species of which approximately one-third are fossils. Four species are known from the Hawaiian Islands.

*Tonna perdx* Linnaeus

*Description:* Shell ovate, thin, large, hard; whorls about six in number; body whorl greatly inflated centrally, encircled by approximately 20 very low, wide, contiguous, spiral ribs; spire not appreciably depressed, longer than in other species; aperture large, somewhat oblique; outer lip simple, thickened, without crenations; columella arched somewhat, but not twisted; color usually reddish-brown, marked by a reticulated pattern of white lines; inner margin of lips white; length, 2 to 6 inches.

This species differs from all other members of the family in its longer spire and more oblique aperture.

The color of this species is not uniform, nor is it enduring. Specimens are known which lack the usual color pattern and, instead, exhibit a nearly uniform coloration over the entire outer surface of the shell. The coloration does not seem to be permanent, for many specimens in collections seem to become progressively lighter with age. This fading appears to be increased by exposure to light.

*Ecology:* This species is by far the most common in Hawaiian waters, being apparently at least twice as abundant as all other species combined. It ranges in depth from less than 10 feet to well over 100 feet and is much more common at the greater depths.

*Distribution:* Circumtropical, including the Hawaiian Islands.

*Tonna melanostoma* Jay

*Description:* Shell ovate, large, thin, hard; whorls about seven in number; body whorl greatly inflated centrally, encircled by 18 to 20 well-defined convex ribs with or without smaller intervening ridges; spire moderately well developed, proportionately shorter than *T. perdx*; aperture large, emarginate basally; outer lip simple, crenate, not thickened; columella expanded, reasonably straight, somewhat twisted, calloused; color of exterior white, yellow, brown, and black, darker in older specimens, grooves darker than intervening ridges; color pattern

irregular but forming poorly defined longitudinal bands of brown, yellow, and white; outer lip marked by black; inner lip marked by black area which becomes large, dark, and shining in older specimens; length, 2 to 9 inches.

*Ecology:* This species is second to *T. perdx* in abundance in Hawaiian waters. It does not seem to invade the shallower areas along the shore line as does *T. perdx* although specimens are not unknown in this area.

This species, like all other shells of this family, is attacked by hermit crabs, including in particular *Dardanus asper* deHaan, the most common of the larger hermit crabs; *Dardanus punctulatus* (Olivier), a large red species measuring as much as 12 inches in length; and another large, white, unidentified species.

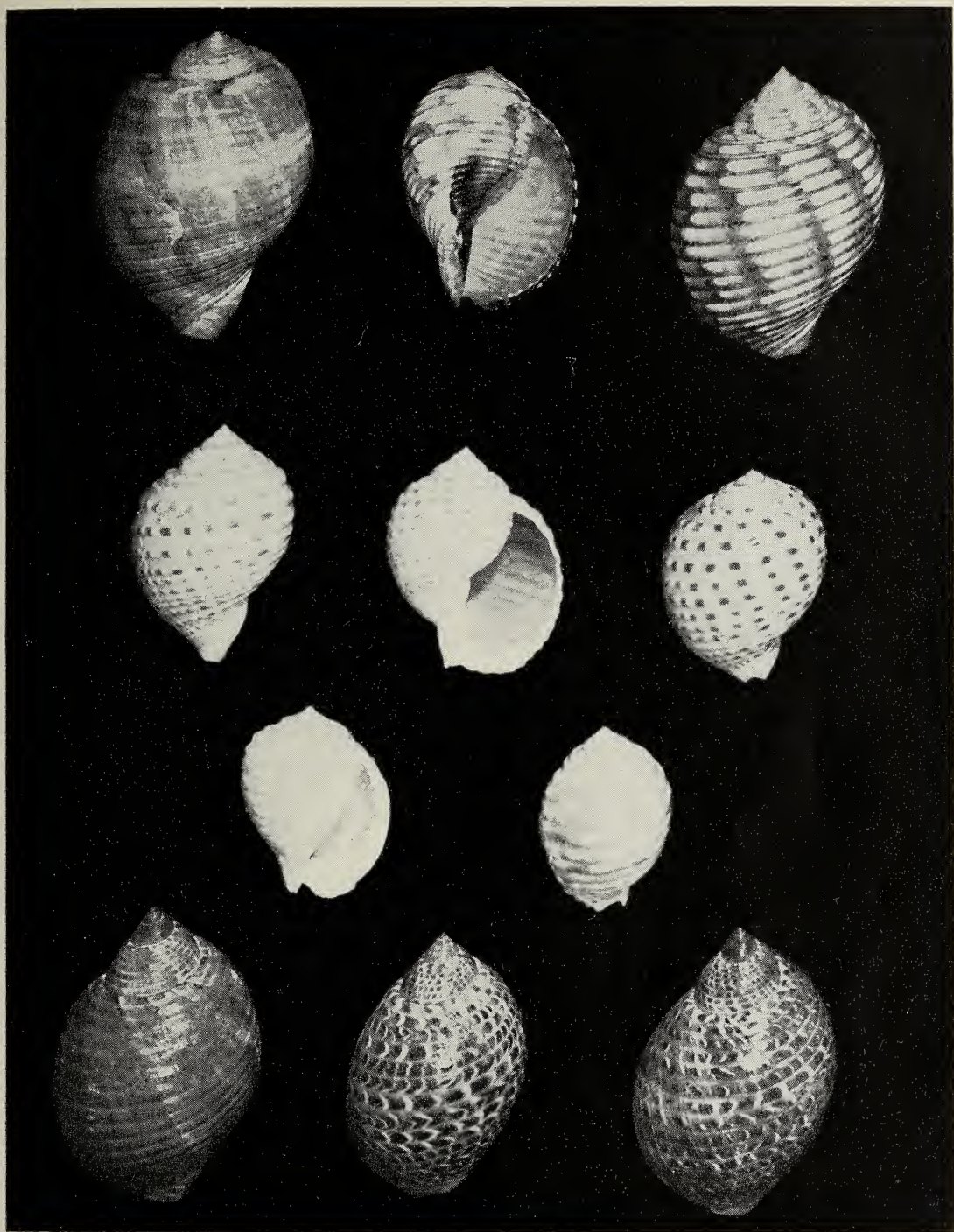
*Distribution:* Indo-Pacific area including the Hawaiian Islands.

*Tonna dolium* (Linnaeus)

*Description:* Shell ovate, large, thin, hard; whorls about six in number; body whorl greatly swollen centrally, encircled by 12 to 16 well-defined spiral ribs which are separated by grooves of the same width with or without a smaller median spiral ridge in each groove; aperture large; outer lip simple, crenate, not thickened; spire normal, with sutures slightly depressed; columella reasonably straight, somewhat twisted; color white or bluish-white, marked by quadrate brown spots upon the ridges, these spots being separated by a distance equal to their width; color of grooves darker than intervening ridges; length, 3 to 5 inches.

*Ecology:* This species is fourth among the tun shells in abundance in Hawaiian waters. It is a rare form and is known only from those specimens mentioned below, all from the same locality. These specimens were procured by Fernando Leonida, a fisherman who operates a set of wire fish traps along the southwest shore of Oahu, and were taken from these wire traps at the outer edge of the reef platform at depths of approximately 15 fathoms. At the time of their capture, all of the specimens were occupied by various species of hermit crabs, a fact which accounts for the presence of the shells





## PLATE I. HAWAIIAN TUN SHELLS

Top row: Left, *Tonna canaliculata* Linnaeus. Center and right, *Tonna melanostoma* Jay.  
Second row: *Tonna dolium* (Linnaeus).  
Third row: *Malea pomum* Linnaeus.  
Bottom row: *Tonna perdix* Linnaeus.

in the fish traps. The shells were covered over the outside and about the aperture by a large and fairly common species of sea anemone, *Calliactis armillatas* Verrill (Sagartidae). Although many of the specimens are not in perfect condition, the characteristics of all of them show well enough to permit identification.

*Distribution:* Indo-Pacific area and the Hawaiian Islands. The occurrence of this species in Hawaiian waters is believed to be unrecorded. A series of more than 25 specimens from the southwestern shore of Oahu has been studied. The Hawaiian specimens from this locality have been distributed to permit their widest use and may now be observed in the following collections: the United States National Museum in Washington, D. C., the Science Museum of the California Academy of Sciences in San Francisco, and in the collections of the Bernice P. Bishop Museum, Ditlev Thaanum, Dr. C. M. Burgess, Dr. Vernon Smith, Arthur Wriston, Charles Allen, and the author, all of Honolulu.

#### *Tonna canaliculata* Linnaeus

*Description:* Shell ovate, large, thin, hard, greatly expanded; whorls about seven in number; body whorl greatly expanded centrally, encircled by about 19 broad, closely set, flat, spiral ribs, separated by comparatively narrow and shallow interspaces, marked at the sutures by a deep channel; columella reasonably straight, but slightly twisted; lip simple; color tawny yellow exteriorly, ribs lighter in color, grooves darker, body whorl becoming increasingly darker toward the lip; length, 3 to 5 inches.

*Ecology:* This species is the rarest of the tun shells in Hawaiian waters, being known in this locality from a single specimen. It is apparently entirely absent in shallow water and very rare at depths of less than 100 feet. The single specimen was occupied by a hermit crab which had carried it into a wire fish trap at a depth of about 15 fathoms.

*Distribution:* Indo-Pacific area including the Hawaiian Islands. The occurrence of this species in Hawaiian waters is based upon a single specimen from the southwestern shore of Oahu in

the collection of the author. This is believed to be the first record of this species from the Hawaiian Islands.

#### Genus *MALEA* Valenciennes

Shell ovate, thin, hard, relatively heavier; whorls less expanded; umbilicated; outer lip simple, outwardly reflected, dentate; aperture reduced.

A single species is known from the Hawaiian Islands.

#### *Malea pomum* Linnaeus

*Description:* Shell ovate, comparatively thin and hard but less so than in genus *Tonna*; whorls about six in number; body whorl moderately large and expanded, but less than in *Tonna*, encircled by about 12 well-defined, low, spiral ribs; spire short; sutures not depressed; outer lip dentate within, reflected flatly outward, somewhat thickened; columellar lip denticulate or wrinkled; columella very slightly excavated at the base; color white, marked with amber of varying intensity and arranged so as to appear spotted with white upon the ridges; lips white; length, 1 to 3 inches.

*Ecology:* This species is the smallest tun shell in Hawaiian waters and the third most abundant, being exceeded in numbers by *T. perdix* and *T. melanostoma*. It is most abundant at depths approaching 100 feet but is occasionally taken in shallower water. It is apparently not as readily sought out by hermit crabs as are the larger species possibly because the dentition of the shell reduces the aperture and restricts movement, or because the shell is heavier to carry and less easily trimmed at the lip to fit the needs of the crabs.

*Distribution:* Indo-Pacific area from the Red Sea to eastern Polynesia and the Hawaiian Islands.

The author acknowledges with pleasure the assistance of Dr. Harald Rehder, Ditlev Thaanum, and Wray Harris in problems of distribution and taxonomy, and the help of Charles Allen, Mrs. Ruth Porter, Kenneth Wong, and Wing You Tong in the preparation of the photograph.



# Factors Influencing the Development of Lateritic and Laterite Soils in the Hawaiian Islands<sup>1</sup>

G. DONALD SHERMAN<sup>2</sup>

THE PARENT MATERIALS of the soil of the Hawaiian Islands have weathered under climatic conditions which are favorable for the development of lateritic and laterite soils. Cline (in press), in his classification of Hawaiian soils, has recognized the following four groups of lateritic and laterite soils: (a) low humic latosols—a group of soils which have developed in regions having a rainfall ranging from 15 to 80 inches. These soils have silica to sesquioxide ratios varying from 1.3 to 1.8; (b) humic latosols—this group of soils has developed in areas having a rainfall from 60 to 150 inches. These soils have developed silica to sesquioxide ratios varying from 0.5 to 0.8; (c) hydrol humic latosols—these soils are found in the regions receiving a very heavy rainfall, 120 to 300 inches. The silica to sesquioxide ratios of this group of soils vary from 0.3 to 0.6; and (d) ferruginous humic latosols—soils belonging to this group have a concentration of heavy minerals in the A<sub>2</sub> horizon. These soils have developed in regions receiving a relatively wide range of rainfall, 25 to 150 inches. The silica to sesquioxide ratios of these soils show great variation, ranging from 0.05 to 1.0.

Each group of soils possesses clays which have distinct and definite chemical properties and these properties were used as a basis for the classification of lateritic soils into the four groups. Since each group of these soils occurs in regions having different climatic conditions, it is likely that climate plays a major role in development. Since the geological ages of the

parent materials vary greatly, the time of exposure of the parent material to soil-forming processes will also have had a major effect on soil development. Due to the great variation of the age of the soil parent material, and the great variation in climate due to the effects of elevation and trade winds on temperatures and rainfall regions, a very complex pattern of soil development has resulted. It is the object of this paper to consider the effects of climate and age on the development of lateritic and laterite soils in the Hawaiian Islands.

## REVIEW OF LITERATURE

Most of the research work involving Hawaiian soils has had for its objective the solution of agronomic problems. Kelley and his co-workers (1912, 1914, 1915) have published several papers on the general chemical composition of certain Hawaiian soils. Moir (1935), in reviewing the work on chemical composition, has concluded that Hawaiian soils have lost a large portion of their silica.

More recently, Hough and Byers (1937) have reported data from a very complete chemical analysis of soils from seven Hawaiian soil profiles. These workers pointed out the very uniform composition of the profiles of the red soils (low humic latosols) and suggested that the clay of these soils was of the kaolinite type. Their data also revealed an unusually high titanium oxide content. Later Hough *et al.* (1941) reported the chemical composition of 21 soil profiles which were selected to range in length of time of weathering from very recent to very old. From the data obtained, these workers suggested that Hawaiian soils were the products of the soil-forming process called podsolization, and were, therefore, podsollic. They based their hypothesis on the following points: first, the

<sup>1</sup> Published with the approval of the Director of the University of Hawaii Agricultural Experiment Station, Honolulu, T. H., as Technical Paper No. 179.

<sup>2</sup> Department of Soils and Agricultural Chemistry, University of Hawaii Agricultural Experiment Station. Manuscript received May 9, 1949.

parent materials of Hawaiian soils, basalt and trachyte, are relatively free of quartz, so that quartz could not accumulate in the A horizon; second, there is an accumulation of titanium oxide in the A horizon of Hawaiian soils. It was their assumption that titanium minerals are resistant to weathering and would, therefore, accumulate where quartz would normally be found in a podsol profile.

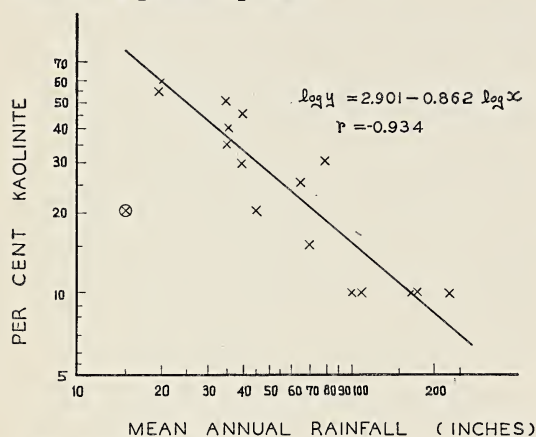


FIG. 1. The relationship between the kaolinite content of the soil colloid and mean annual rainfall.

Dean (1947) and Tanada (1944) have shown that a high kaolinite content in Hawaiian soils developed in regions receiving 25–35 inches of rainfall annually and that the kaolinite content decreased with increasing rainfall. This relationship between rainfall and kaolinite content is illustrated in Figure 1. Subsequent work has shown that the kaolinite content in certain Hawaiian soils (ferruginous humic latosols) decreases with age regardless of the amount of rainfall under which the soil has developed (Sherman *et al.*, 1949). The results of work in our laboratories have supported the hypothesis that in the weathering of tropical soils two weathering processes are occurring, namely, clay mineral formation (kaolinization) from the decomposition of primary minerals of the soil parent material, and clay mineral decomposition with free oxide accumulation from the decomposition of the kaolinite type of clay minerals. The recent publications from this Station (Sherman *et al.*, 1949, and Fujimoto *et al.*, 1949)

have described soils belonging to the ferruginous humic latosol in which the kaolinite clay minerals have undergone almost complete decomposition resulting in the development of soil horizons having a high concentration of iron and titanium oxides. Hematite, goethite, and anatase have been identified as the dominant minerals occurring in these horizons.<sup>3</sup> The decomposition of the kaolinite and the accumulation of these free oxides of secondary origin have occurred under a rainfall of 35 inches per annum and thus can be attributed only to age.

Mohr (1944), in describing the factors which influence soil weathering in tropical regions, has placed considerable emphasis on the part played by rainfall distribution, profile drainage, and age or time of exposure to soil forming processes. He has divided the types of rainfall distribution into five groups, depending on the number of months receiving an average monthly rainfall of less than 60 mm. (which are classified as dry months) and the number of months receiving an average rainfall higher than 100 mm. (which are classified as wet months). His groups range from regions in which most of the months are classified as dry, to regions which are predominantly wet. Closely associated with the distribution of rainfall is the type of water movement in the soil. This is extremely important in tropical regions since the internal drainage soils may be restricted due to formation of impervious clay layers. Under appreciable rainfall this can produce conditions which result in the upward movement, from the zone of saturation, of a considerable portion of the water entering the soil and the lateral movement of water through the horizons of soils which have developed on slopes.

Mohr (1944), in his discussion of the age of soils, recognizes five stages of soil weathering. The five stages of soil weathering which he feels every soil must pass through are fresh, juvenile, virile, senile, and "laterite." According to his hypothesis, the end-product of tropical soil

<sup>3</sup>Cooperative studies with Dr. M. L. Jackson, University of Wisconsin.



weathering will be the iron oxide "laterite crust" as the surface soil and a layer of bauxite as the subsoil.

The soil associations which occur in the Hawaiian Islands appear to fit into several phases of Mohr's hypothesis of tropical soil weathering. The distribution of rainfall in the Hawaiian Islands fits all five of Mohr's groups. Laterization is occurring in soils which have developed in areas which are predominantly dry, those which have alternating wet and dry seasons of variable duration, and under predominantly wet and continuously wet conditions. Also there is good evidence that examples of all five stages of soil weathering described by Mohr do exist in the Hawaiian Islands. The recent discovery of a soil horizon resembling the "laterite crust" supports this contention (Fujimoto *et al.*, 1949).

RELATIONSHIP OF SOIL GROUPS TO  
RAINFALL DISTRIBUTION IN THE  
HAWAIIAN ISLANDS

The Hawaiian soils which are developed by the soil-forming process, laterization, occur under a wide range of rainfall. Casual observations would suggest that each of the latosol groups

occurs under rather definite regions of rainfall distribution. Further inspection of the actual rainfall for each month at different locations on the island of Oahu revealed a similar rainfall distribution for soils belonging to each latosol group. The data given in Table 1 were obtained by classifying the rainfall distribution of the regions where each soil group is developed according to the wet and dry months proposed by Mohr (1944). The data show that the soils belonging to the low humic latosol and the ferruginous humic latosol have a definite dry season. The lack of a clear-cut difference between the rainfall distribution would suggest that the ferruginous humic latosol may develop from the low humic latosol with age. The humic and hydrol humic latosol have developed under continuous wet conditions. The data include the number of very wet months, or the months receiving more than 8 inches of rainfall. This information is given to show the very wet condition under which the hydrol humic latosols are developed. The chemical analysis of soils has revealed a marked difference in the composition of soils developed in the regions having a definite dry season and of the soils developed under continuous wet conditions. The

TABLE 1  
THE RELATIONSHIP BETWEEN THE RAINFALL DISTRIBUTION AND SOIL GROUPS DEVELOPED ON THE ISLAND OF OAHU\*

GREAT SOIL GROUP	SOIL FAMILY	NO. OF DRY MONTHS†	NO. OF INTER-MEDIATE RAINFALL MONTHS†	NO. OF WET MONTHS†	NO. OF VERY WET MONTHS†
Low humic latosol.....	Molokai	8	4	0	0
Low humic latosol.....	Lahaina	6	6	0	0
Low humic latosol.....	Wahiawa	5	4	0	0
Low humic latosol.....	Kahana	2	7	3	0
Low humic latosol.....	Kohala	1	4	8	0
Ferruginous humic latosol.....	Mahana	9	2	1	0
Ferruginous humic latosol.....	Naiwa	5	3	4	0
Humic latosol.....	Kaneohe	1	5	6	0
Humic latosol.....	Honolua	0	4	8	0
Hydrol humic latosol.....	Koolau	0	0	8	4
Hydrol humic latosol.....	Koolau	0	0	3	9

\* Mohr's definition of dry and wet months was based on mean monthly rainfall. The data given in this table are based on monthly median rainfall as presented by Halstead and Leopold (1948).  
† Dry months, less than 2 3/8 inches of rainfall; intermediate rainfall months, 2 3/8-4 inches; wet months, 4-8 inches; very wet months, more than 8 inches.

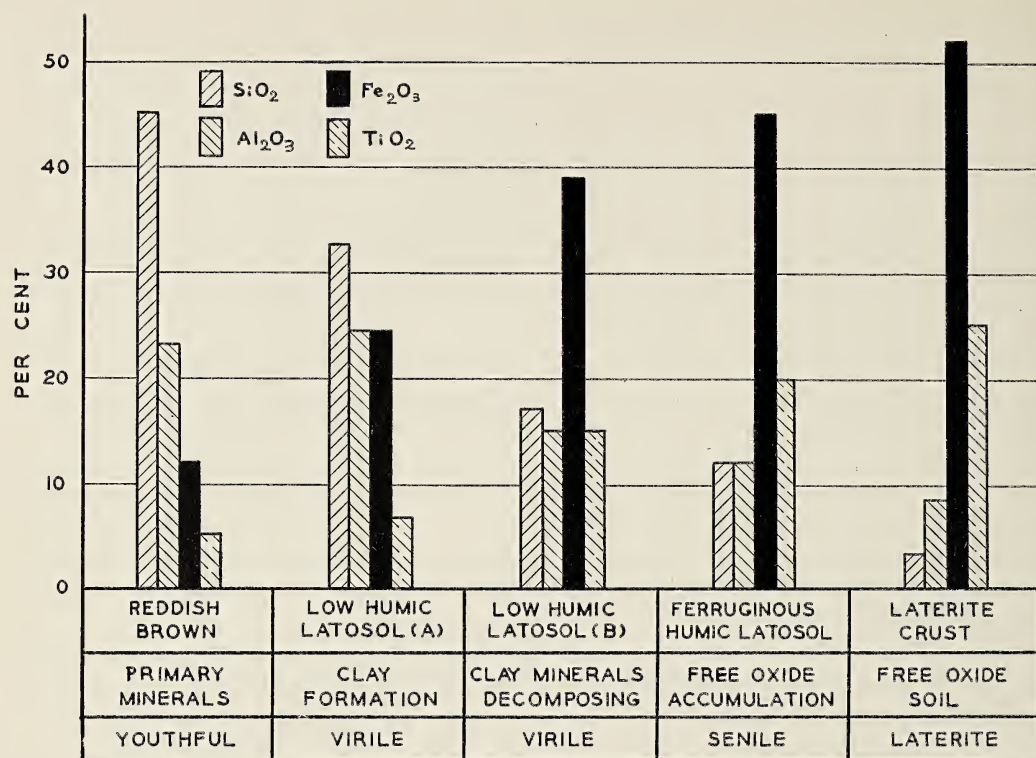


FIG. 2. The influence of the lengthening of the wet season of an alternating wet and dry season climate on the chemical composition of the A horizon of the soil. The wet season increases in this series of soils from left to right. (A) and (B) profiles are two different soils belonging to the low humic latosol.

fact that the soils differ greatly in their chemical composition and physical properties would indicate that the distribution of rainfall must play an important role in the type of weathering which has occurred in the soil.

#### CHEMICAL COMPOSITION OF SOILS DEVELOPED UNDER A DEFINITE DRY SEASON

The chemical analysis of several soil profiles belonging to the low humic latosol and ferruginous humic latosol to determine their "major" oxide content was made by methods described by Piper (1944). The soils were selected to represent the following successive stages of weathering: (a) the youthful soil containing most of its primary minerals; (b) the peak of clay formation—kaolinization; (c) the stages showing the cessation of clay formation and the increasing oxide formation or

clay mineral decomposition; and (d) the final end-product of weathering—the free oxide soil. With the exception of the end-product stage, these stages of soil weathering are found under increasing rainfall. The end-product stage—the oxide soil—exhibits evidence of lateral movement of water through the soil solum. Likewise, the stages of soil weathering exhibit the progressive effect of the shortening of the drought season of these soils.

The results obtained from the analysis of soil samples from the A horizons of the selected soil profiles presenting successive weathering stages are shown graphically in Figure 2. The data show a steady decrease in the silica content of the A horizons with the advancement in the weathering of the soil. Alumina content of the soil increases with the clay formation and decreases rapidly as the clay minerals decompose. The iron and titanium oxides accumulate as the



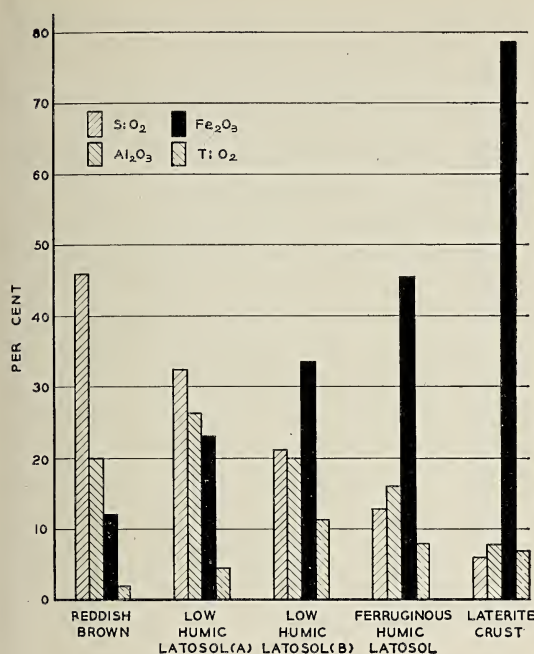


FIG. 3. The influence of the lengthening of the wet season on the chemical composition of the B horizons of the soils shown in Figure 2. (A) and (B) profiles represent two low humic latosols.

soil weathering progresses and in the "laterite crust" they constitute almost 80 per cent of the soil. These oxides are present as two secondary minerals—hematite and anatase.

The data presented graphically in Figure 3 were obtained from the chemical analysis of soil samples representing the B horizons of the soils shown in Figure 2. The silica, alumina, and iron oxide show exactly the same trends as were found for the soils representing the A horizon. Titanium oxide content of the B horizons fails to increase with weathering. Since these soils are very acid, it is probable that the titanium was converted to metatitanic acid and moved upward to the A horizon where it was dehydrated during the dry seasons ultimately to form anatase. The iron oxide of the B horizon of the "laterite crust" exists as hematite and goethite.

The data presented in Figures 2 and 3 represent, in general, a sequence of conditions em-

phasizing a range in the proportion of dry months to wet months. The range spans from 12 dry months to approximately 3 dry, 3 wet, and 6 intermediate months per year in the ferruginous humic latosol. It is obvious that the effectiveness of an alternating wet and dry season on the rate of soil weathering is governed by the following factors: (a) amount of rainfall during the wet season and (b) the intensity and duration of the dry season. However, the question arises as to the effect of time. Will the soils belonging to the low humic latosol continue to weather until they take on the characteristics of the ferruginous humic latosol? It is reasonable to assume that they will continue to weather toward the end-product, the "laterite crust." The following evidence would support this contention: (a) the increase in area of soils belonging to the ferruginous humic latosol with the geological age of the parent materials and a simultaneous decrease in area of the soils belonging to the low humic latosols. The island of Kauai, geologically the oldest of the major Hawaiian islands, has the greatest area of ferruginous humic latosols, and the low humic latosols show greater advancement in weathering than the same type of soil on younger islands; (b) the decrease in kaolinite content and the increase in iron oxide content in low humic latosols on the older geological parent materials; (c) the occurrence of the "laterite crust" on relatively dry slopes receiving a rainfall comparable to that of the drier low humic latosols on the island of Kauai; and (d) the increase in compaction of the subsoils of the low humic latosols with age, which may favor formation of an impervious subsoil which will in turn develop conditions favorable for the lateral movement of water through those soils occurring on slopes. In the drier regions of the low humic latosols the rainfall will probably never be sufficient in quantity to produce this transformation but in those which have a definite wet season, time will certainly produce ferruginous humic latosol.

CHEMICAL COMPOSITION OF THE SOILS  
DEVELOPED IN AN ABSENCE OF  
A DEFINITE DRY PERIOD

The soils belonging to the humic latosol and the hydrol humic latosol have been developed under conditions in which the soil solum rarely dries out. These soils in the Hawaiian Islands are covered with dense cover of ohia, tree ferns, and staghorn fern. The latter two produce an extremely acid forest floor (Sherman, 1947). These soils have been separated in the field on the basis of their clay properties. The clay of the humic latosol can be pressed into a ribbon between one's fingers while that of the hydrol humic latosol will smear. A series of soil profiles representing a sequence of these clays developed under increasing rainfall was selected for analysis. These soils range from a soil profile belonging to an intrazonal group (brown forest) developed under 70 inches of rain per annum to a hydrol humic latosol profile developed under 273 inches of rain per annum; all have developed on parent materials made up of volcanic

ash. The data obtained from these analyses are given graphically in Figure 4.

The data presented in Figure 4 show an increase in the alumina content with an increase in rainfall. The silica and iron oxide content appears to decrease with an increase in rainfall. This would suggest that under continuously wet conditions the alumina will become stabilized and iron oxide will become unstable and leach away. Tanada (1944) has identified bauxite and limonite as the minerals representing alumina and iron oxide in these soils. It is likely that as this soil continues to weather, the bauxite will continue to accumulate as a result of the destruction of the kaolinite clay minerals and the removal of silica and iron oxide by leaching. Thus, the end-product of weathering in the very wet tropics will probably be a "bauxite laterite."

#### DISCUSSION

The author has presented two sequences of soil weathering which are considered to be fun-

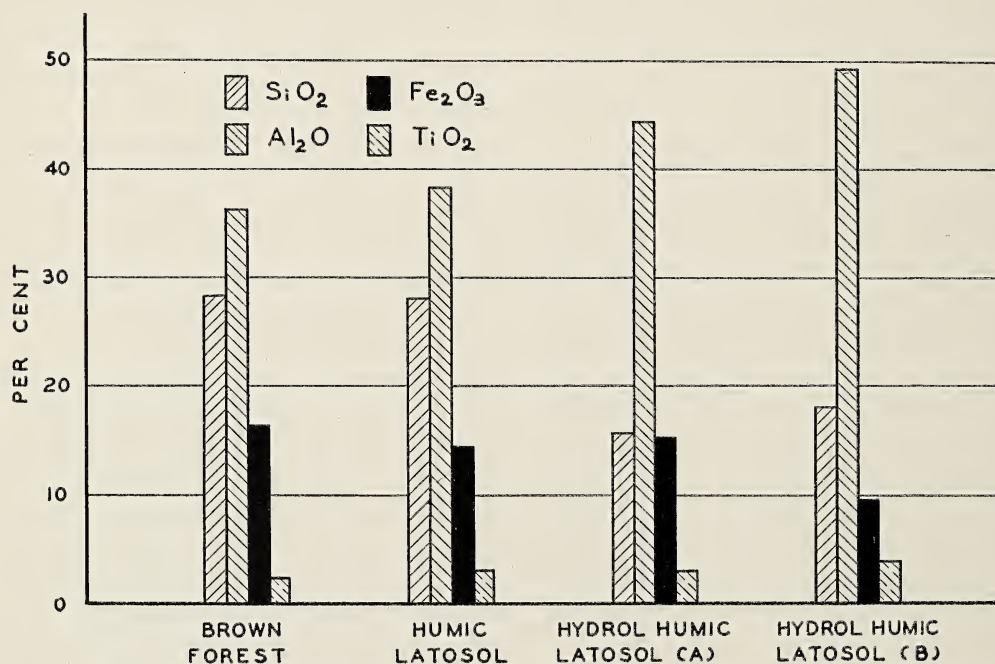


FIG. 4. The influence of an increase in annual rainfall on the chemical composition of soils developed in a continuously wet region.



damental in any interpretation of the soil associations which occur in tropical regions. In this presentation every effort has been made to avoid the complexities in the soil associations due to transition zones, degradation due to shifting climatic conditions or to lowering of the general elevation of volcanic areas, and differences in the composition of the weathered geological materials.

The initial weathering of parent materials is the breakdown of the primary minerals with the formation of secondary clay minerals of the kaolinite type. The rate of decomposition of the kaolinite minerals appears to be closely related to the amount of rainfall under which the soil is formed. Under extremely heavy rainfall the formation of the secondary clay mineral and its subsequent decomposition may be so rapid and transitory as to leave the outline of the original minerals and stratification of the parent materials. The hydrol humic latosols often show the stratification of the original parent material.

The distribution of rainfall plays an important role in the nature of the ultimate end-product of laterization in tropical soils. The stabilization of the iron oxide in soil has resulted from an alternating wet and dry season climate. Under a continuously wet soil profile environment, alumina becomes the stabilized free oxide. The amount of iron remaining in these soils depends on the amount of rainfall and aeration. This would explain to some degree the occurrence of aluminum oxide laterites and iron oxide laterites. The effect of the alternating wet and dry season can be destroyed by the development of a poor internal drainage in the soil solum. If this condition promotes lateral movement of water, as it will on slopes, it will facilitate the development of the iron oxide "laterite crust." If the impervious condition produces a stagnation of the water in the profile, a certain amount of resilication will take place with the removal of the easily reducible iron in the slow leaching of the impervious layer. The result of this condition will be the development of the profile of a very wet soil.

## CONCLUSION

The data presented in this paper have emphasized several important fundamental reactions which occur in tropical soil. In the development of tropical soils two weathering actions are taking place: (a) the formation of clay minerals of kaolinite type from the primary minerals, and (b) the decomposition of the clay minerals with the accumulation of free oxides of iron, aluminum, and titanium.

The distribution of the rainfall and proportion of months receiving less than  $2\frac{3}{8}$  inches of rain (the dry months) and the months receiving more than 4 inches (the wet months), play an important role in the nature of the free oxides which will become stabilized and will accumulate in the soil solum. In evaluating the quantity of rainfall it was found necessary to introduce the number of very wet months (more than 8 inches of rain) in order to differentiate between the humic latosol and hydrol humic latosol which are developed under very wet conditions.

The low humic latosol and the ferruginous humic latosol have developed in a climate having a definite dry season alternating with a wet season of varying length and intensity. The soils developed under this type of season would exhibit the following chemical properties with increased weathering due either to the intensity of the alternating wet or dry conditions or to time of exposure of this type of weathering condition: (a) in the early stages both the kaolinite and alumina content increase and both decrease with further weathering; (b) silica content of the soil decreases with the age of weathering of the soil; (c) the content of iron and titanium oxides in the soil increases with the weathering age of the soil; and (d) the final end-product of weathering under these conditions is a "laterite crust" having a high content of iron and titanium minerals.

The humic latosol and hydrol humic latosol are developed under climates which have no definite dry season. Soils developed under these conditions have the following chemical properties: (a) the rapid decomposition of the clay

minerals to the free oxides; (b) an increase in the alumina content with increase in rainfall; (c) decrease in the content of silica and iron oxide with increase in rainfall; and (d) the ultimate end-product of soil weathering will be an "aluminum oxide laterite," probably a "bauxite laterite."

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# Catalogue of the Heterocerous Lepidoptera from French Oceania

PIERRE E. L. VIETTE<sup>1</sup>

INFORMATION ABOUT the lepidopterous fauna of the French territories in the Pacific Ocean is scarce. Aside from the original descriptions, no whole study has been carried out for New Caledonia, the Loyalty Islands, or the New Hebrides. The lepidopterous material collected by F. Sarrasin and J. Roux during their mission (1911) in the first two of these countries has never been studied. The fauna of the other French islands (Society Islands, Marquesas, Archipelago of the Tuamotus, Austral Islands, Gambier Islands) is better known through, first, the material collected by Miss Cheesman during the St. George Expedition (1924–1925) of which the Rhopalocera were studied by Poulton and Riley (1928), the Macroheterocera by Collenette (1928) and Prout (1929), and the "Micros" by Meyrick (1928–1929); and, second, through the material (Micros), collected by the Pacific Entomological Survey, which was studied by Meyrick (1935 *a, b*).

I have covered elsewhere (*Lépidoptères Rhopalocères de l'Océanie française. Faune de l'Empire*, Editions du Museum, Paris [in press]) the Rhopalocera of these regions, so here I present only a catalogue of the Heterocera. The information both is bibliographical and founded upon the insects present in the collections of the Department of Entomology of the National Museum of Natural History of Paris. Insects were brought to France by people who stayed in those regions (Marie, Joly, Quod, Mrs. Pruvot, Aubert de la Rüe, Risbec, Catala). In spite of this, there is still very much to do, especially for the "Micros" of New Caledonia, Loyalty Islands, and New Hebrides. Many gaps exist; thus all the species

described belong to the group Heteroneura Ditrysia; the suborder Homoneura and the Heteroneura Monotrysia are at present unknown. I am therefore unable, for the time being, to study this group in the same way I have the Rhopalocera, which have always been the first Lepidoptera studied in a given area and which are, on the whole, well known. The publication of this catalogue, the first step towards the knowledge of the lepidopterous fauna of these regions, will be, I hope, a first clearing for the lepidopterists who will go to these districts.

Very many species, especially in the New Caledonia, Loyalty Islands, and New Hebrides areas might still be signalized, either as new, or as belonging to the peripheral areas (Australia, New Guinea, etc.).

I have followed the order given by Zerny and Beier (1936) for the order of the families. Within each family or sub-family, the order followed, when it exists, is that of the *Lepidopterorum Catalogus*. For the Noctuidae, Hampson (1903 to 1913) has been taken as a guide.

So as not to lengthen an already very long list of references, the references of the genera are not shown on this list. They can easily be found in S. A. Neave's *Nomenclator Zoologicus*, 4 vol. Zool. Soc. London, London 1939–1940. References to endemic genera are given, however.

## Family TINEIDAE

NESOXENA Meyrick (1928*a*: 506)

*N. strangulata* Meyrick (1928*a*: 507). Archipelago of the Tuamotus: Fakarava ("St. George" Exped.).

TINEA Denis and Shiffermuller

*T. monospila* Meyrick (1928*a*: 507). Society Islands: Tahiti ("St. George" Exped.).

<sup>1</sup> Department of Entomology, National Museum of Natural History, Paris. Manuscript received July 8, 1948.

- T. despecta* Meyrick (1919: 274). Marquesas Islands: Hiva Oa (Meyrick, 1935*b*).  
*T. paralonoma* Meyrick (1928*b*: 427). New Hebrides: Efate (Meyrick, l.c.).

CARYOLESTIS Meyrick (1935*a*: 109)

- C. praedatrix* Meyrick (1935*a*: 110). Society Islands: Tahiti (Meyrick, l.c.). Larva on coconut.

CYNOMASTIX Meyrick (1930: 548)

- C. rorhodoxa* Meyrick (1930: 548). New Caledonia: Noumea (Cockerell).

#### Family LYONETIIDAE

OPOGONA Zeller

- O. aurisquamosa* Butler (1881: 403). Society Islands: Tahiti ("St. George" Exped.). Marquesas Islands (Meyrick, 1928*a*): Eiao, Fatu Hiva, Uahuka (Meyrick, 1935*b*).  
*O. trissostacta* Meyrick (1935*b*: 354). Marquesas Islands: Uahuka, Hiva Oa (Meyrick, l.c.).

PISISTRATA Meyrick (1924: 81)

- P. trypheropa* Meyrick (1924: 81). Society Islands: Tahiti ("St. George" Exped.). Type from Samoa.

ERECHTHIAS Meyrick

- E. zebrina* Butler (1881: 403). Society Islands: Raiatea ("St. George" Exped.).  
*E. flavistriata* Walsingham (1907: 716). Marquesas Islands: Fatu Hiva ("St. George" Exped.).

DECADARCHIS Meyrick

- D. minuscula* Walsingham (1907: 716). Marquesas Islands: Nuka Hiva ("St. George" Exped.).  
*D. pelotricha* Meyrick (1926: 275). Society Islands: Tahiti, Raiatea. Rapa Island ("St. George" Exped.).  
*D. clistopa* Meyrick (1928*a*: 506). Marquesas Islands: Nuka Hiva ("St. George" Exped.).  
*D. physocapna* Meyrick (1928*a*: 506). Marquesas Islands: Hiva Oa ("St. George" Exped.).  
*D. malthaca* Meyrick (1928*b*: 401). New

Hebrides: Ambryn (Buxton).

- D. capnographa* Meyrick (1928*b*: 402). New Hebrides: Tanna (Buxton).  
*D. platyrrhyncha* Meyrick (1928*b*: 402). New Hebrides: Efate (Buxton).  
*D. simulans* Butler (1879: 164). Society Islands: Raiatea. Marquesas Islands: Tahuata ("St. George" Exped.; Meyrick, 1935*b*), Uahuka (Meyrick, 1935*b*).  
*D. psammaula* Meyrick (1921: 459). Society Islands: Tahiti. Austral Islands ("St. George" Exped.).  
*D. coleosema* Meyrick (1935*b*: 354). Marquesas Islands: Hiva Oa (Meyrick, l.c.).  
*D. persnomicta* Meyrick (1935*b*: 355). Marquesas Islands: Eiao.  
*D. rufimacula* Meyrick (1935*b*: 355). Marquesas Islands: Uapou (Meyrick, l.c.).

#### Family PLUTELLIDAE

TRACHYCENTRA Meyrick (1886: 288)

- T. calamias* Meyrick (1886: 288). Marquesas Islands: Nuka Hiva ("St. George" Exped.). Type from Tonga and Fiji.

MASTIGOSTOMA Meyrick

- M. halithea* Meyrick (1927*a*: 330). New Hebrides: Tanna (Buxton and Hopkins).

#### Family GRACILARIIDAE

EPICEPHALA Meyrick

- E. colymbetella* Meyrick (1880: 169). Marquesas Islands: Nuka Hiva ("St. George" Exped.).

PARECTOPA Clemens

- P. pontificalus* Meyrick (1928*a*: 505). Austral Islands: Rurutu ("St. George" Exped.).

GRACILARIA Haworth

- G. hilaropis* Meyrick (1926: 274). Rapa Island (Meyrick, l.c.).  
*G. crysidelta* Meyrick (1926: 275). Rapa Island (Meyrick, l.c.).  
*G. scaeodesma* Meyrick (1928*b*: 409). New Hebrides (Buxton).  
*G. deltanthes* Meyrick (1935*b*: 354). Marquesas Islands: Uapou (Meyrick, l.c.).



## Family COLEOPHORIDAE

## AGONOXEMA Meyrick

- A. *pyrogramma* Meyrick (1924: 84). New Hebrides. On the "Sagoutier" (Risbec, 1942).  
 A. sp. Parasite of the coconut tree in New Caledonia (Risbec, 1942).

## Family HYPONOMEUTIDAE

## ZELLERIA Stainton

- Z. *leucostra* Meyrick (1928a: 504). Marquesas Islands: Nuka Hiva, Tahuata ("St. George" Exped.).

## ATTEVA Walker

- A. *sphaerotrocha* Meyrick (1936: 41). New Caledonia (Meyrick, l.c.).  
 A. *mathewi* Butler (1887a: 414). New Hebrides (Paris Museum, coll. de Joannis).

## Family ELACHISTIDAE

## PERSICOPTILIA Meyrick (1886: 295)

- P. *erythrota* Meyrick (1886a: 295). New Hebrides (Mathew).

## Family GLYPHIPTERYGYDAE

## IMMA Walker

- I. *chloroplintha* Meyrick (1928a: 503). Society Islands: Tahiti ("St. George" Exped.).  
 I. *oxypeselia* Meyrick (1928a: 503). Society Islands: Raiatea ("St. George" Exped.).  
 I. *semiclara* Meyrick (1928a: 503). Marquesas Islands: Hiva Oa, Nuka Hiva, Tahuata ("St. George" Exped.).  
 I. *catapsesta* Meyrick (1935b: 352). Marquesas Islands: Fatu Hiva, Uahuka, Nuka Hiva, Upou, Hiva Oa (Meyrick, l.c.).  
 I. *fulminatrix* Meyrick (1935b: 353). Marquesas Islands: Hiva Oa (Meyrick, l.c.).

## LOXOTROCHIS Meyrick (1906: 205)

- L. *sepias* Meyrick (1906: 205). New Hebrides: Espiritu Santo (Meyrick, l.c.).

## TORTYRA Walker

- T. *tabularia* Meyrick (1912: 37). Loyalty Islands: Lifu (Meyrick, l.c.).

## SIMAETHIS Leach

- S. *chelapsis* Meyrick (1928a: 504). Marquesas Islands: Hiva Oa ("St. George" Exped. and Meyrick, 1935b), Upou (Meyrick, 1935b).  
 S. *orthogona* Meyrick (1886a: 287). Society Islands: Tahiti, Bora Bora ("St. George" Exped.). Type from New Guinea.  
 S. *chalcotoxa* Meyrick (1886a: 287). Society Islands: Bora Bora ("St. George" Exped.). Type from Tonga and Fiji.

## Family SCHRECKENSTEINIIDAE

(= Heliodinidae)

## STATHMOPODA Stainton

- S. *cryptophaea* Meyrick (1922: 585). Society Islands: Tahiti (Paris Museum, coll. de Joannis).  
 S. *mesocrossa* Meyrick (1927a: 379). New Hebrides: Efate (Buxton).  
 S. *electrantha* Meyrick (1927a: 377). New Hebrides; Tanna (Buxton and Hopkins).

## PACHYRABDA Meyrick

- P. *euphanopis* Meyrick (1927a: 377). New Hebrides: Espiritu Santo (Buxton).

## LISSOCNEMITIS Meyrick (1935b: 352)

- L. *argolyca* Meyrick (1935b: 352). Marquesas Islands: Hiva Oa (Meyrick, l.c.).

## Family COPROMORPHIDAE

## DRYANASSA Meyrick (1936: 40)

- D. *erebactis* Meyrick (1936: 40). Society Islands: Tahiti (Meyrick, l.c.).

## Family ORNEODIDAE

## ORNEODES Latreille

- O. *pselioxantha* Meyrick (1928a: 502). Archipelago of the Tuamotus: Fakarava ("St. George" Exped.).

## Family CARPOSINIDAE

## CARPOSINA Herrich Schäffer

- C. *stationaria* Meyrick (1928b: 403). New Hebrides: Tanna (Buxton).  
 C. *asbolopis* Meyrick (1928b: 403). New Hebrides: Tontouta (Buxton).

## MERIDARCHIS Zeller

- M. pelograpta* Meyrick (1928*a*: 502). Austral Islands: Rurutu ("St. George" Exped.).

## Family OECOPHORIDAE

## BATHRAULA Meyrick

- B. simulatella* Walker (1864*b*: 747). Society Islands: Tahiti (Gaede, 1938: 91).

## Family COSMOPTERYGIDAE

## COSMOPTERYX Hübner (1825: 274)

- C. aphranassa* Meyrick (1926: 274). Rapa Islands (Meyrick, l.c.).  
*C. flavofasciata* Wollaston (1879: 438). Society Islands ("St. George" Exped.).  
*C. melanarches* Meyrick 1928*a*: 497). Society Islands: Raiatea (Meyrick, l.c.).

## PYRODERCES Herrich Schäffer

- P. incertulella* Walker (1864*b*: 748). Austral Islands: Rurutu ("St. George" Exped.). Risbec (1942: 19) names a *Pyroderces* but does not give the name of the species; a parasite of cotton in New Caledonia.  
*P. syngalactis* Meyrick (1928*b*: 382). New Hebrides: Efate, Espiritu Santo (Buxton).  
*P. lunulifera* Meyrick (1935*b*: 347). Marquesas Islands: Hiva Oa, Eiao, Tahuata, Fatu Hiva, Uapou (Meyrick, l.c.).

## PERSICOPTILA Meyrick (1886: 295)

- Pe. erythrota* Meyrick (1886*a*: 295). New Hebrides (Mathew).  
*Pe. heroica* Meyrick (1928*b*: 391). New Hebrides: Tanna, Ambryn, Efate (Buxton).

## BATRACHEDRA Stainton

- B. arenosella* Walker (1864*b*: 857). New Hebrides. Parasite of cotton.

## HEDROXENA Meyrick (1924: 92)

- H. barbara* Meyrick (1924: 92). New Hebrides: Espiritu Santo (Simmonds).

## LABDIA Walker

- L. clodiana* Meyrick (1927*a*: 384). New Hebrides: Efate, Ambryn (Buxton).  
*L. leucoxantha* Meyrick (1927*b*: 87). Mar-

quesas Islands: Uapou, Hiva Oa (Meyrick, 1935*b*). Type from Samoa.

- L. saliens* Meyrick (1928*b*: 384). New Hebrides: Efate, Ambryn (Buxton).  
*L. crocopa* Meyrick (1928*b*: 385). New Hebrides: Tanna (Buxton).  
*L. torodoxa* Meyrick (1928*b*: 386). New Hebrides: Espiritu Santo, Ambryn, Efate (Buxton).  
*L. cedrinopa* Meyrick (1928*b*: 386). New Hebrides: Efate (Buxton).  
*L. semnolitha* Meyrick (1928*b*: 386). New Hebrides: Espiritu Santo (Buxton).

## TRISSODORIS Meyrick

- T. honorarielle* Walsingham (1907: 515, XV, 21). Marquesas Islands: Fatu Hiva, Hiva Oa (Meyrick, 1935*b*). Also in Samoa.

## STAGMATOPHORA Herrich Schäffer

- S. spintheropa* Meyrick (1935*b*: 348). Marquesas Islands: Uapou (Meyrick, l.c.).

## LIMNAECIA Stainton

- L. microglypta* Meyrick (1928*b*: 393). New Hebrides: Efate, Espiritu Santo (Buxton).  
*L. astathopis* Meyrick (1935*b*: 393). Marquesas Islands: Hiva Oa (Meyrick, l.c.).

ASYMPHORODES Meyrick (1928*b*: 498)

- A. perfuga* Meyrick (1926: 274). Rapa Island, with the name *Ulochora perfuga*.  
*A. coesyrias* Meyrick (1928*a*: 498). Marquesas Islands: Tahuata, Hiva Oa ("St. George" Exped.; Meyrick, 1935*b*). Nuka Hiva ("St. George" Exped.).  
*A. valligera* Meyrick (1928*a*: 498). Marquesas Islands: Hiva Oa ("St. George" Exped.).  
*A. plectographa* Meyrick (1928*a*: 498). Marquesas Islands: Hiva Oa ("St. George" Exped.).  
*A. sphenocopa* Meyrick (1928*a*: 499). Marquesas Islands: Nuka Hiva, Hiva Oa, Fatu Hiva, Tahuata ("St. George" Exped.).  
*A. leucoterma* Meyrick (1928*a*: 499). Marquesas Islands: Hiva Oa ("St. George" Exped.).



*A. circopis* Meyrick (1928*a*: 499). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. nephocirca* Meyrick (1928*a*: 500). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. interstincta* Meyrick (1928*a*: 500). Archipelago of the Tuamotus: Fakarava ("St. George" Exped.).

*A. polluta* Meyrick (1928*a*: 500). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. cirsodes* Meyrick (1928*a*: 500). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. myronota* Meyrick (1928*a*: 500). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. porphyrrarcha* Meyrick (1928*a*: 501). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. monoxesta* Meyrick (1928*a*: 501). Society Islands: Tahiti ("St. George" Exped.).

*A. chalcozona* Meyrick (1935*a*: 109). Society Islands: Tahiti.

*A. admiranda* Meyrick (1935*b*: 349). Marquesas Islands: Uapou.

*A. oculisignis* Meyrick (1935*b*: 349). Marquesas Islands: Hiva Oa.

*A. ingravescens* Meyrick (1935*b*: 350). Marquesas Islands: Hiva Oa.

*A. xanthostola* Meyrick (1935*b*: 350). Marquesas Islands: Hiva Oa, Uapou.

*A. xestophanes* Meyrick (1935*b*: 351). Marquesas Islands: Hiva Oa.

*A. ergodes* Meyrick (1935*b*: 351). Marquesas Islands: Hiva Oa.

*A. acrophrictis* Meyrick (1935*b*: 351). Marquesas Islands: Uapou.

*A. balanotis* Meyrick (1935*b*: 351). Marquesas Islands: Eiao, Hiva Oa.

*A. holoporphyrha* Meyrick (1935*b*: 352). Marquesas Islands: Hiva Oa.

*MICROZESTIS* Meyrick (1928*a*: 501)

*M. inelegans* Meyrick (1928*a*: 502). Marquesas Islands: Tahuata, Hiva Oa ("St. George" Exped.).

## Family GELECHIIDAE

### ANARSIA Zeller

*A. anthracaula* Meyrick (1929*b*: 512); Gaede (1937: 401). New Hebrides: Tanna (Aubert de la Rüe), Efate (Buxton).

### PLATYEDRA Meyrick

*P. gossypiella* Saunders (1843: 284); Gaede (1937: 231). New Caledonia (Risbec, 1942). Society Islands: Raiatea ("St. George" Exped.).

### GNORIMOSCHEMA Busck

*G. operculella* Zeller (1873: 262, III, 17); Gaede (1937: 277). New Caledonia (Risbec, 1942; Barrau); on cotton and tobacco. Marquesas Islands: Hiva Oa ("St. George" Exped.).

### DICHOMERIS Hübner

*D. resignata* Meyrick (1929*b*: 510); Gaede (1937: 552). New Hebrides: Espiritu Santo (Buxton).

### STOEBERHINUS Butler (1881: 402)

*S. testacea* Butler (1881: 402); Gaede (1937: 552). New Hebrides. Marquesas Islands: Nuka Hiva, Hiva Oa, Fatu Hiva, Tahuata. Society Islands: Tahiti, Raiatea. Austral Islands: Rurutu. Rapa Island. Archipelago of the Tuamotus: Napuka ("St. George" Exped.). Type from Hawaii. Also in 'Fiji and Samoa.

### AUTOSTICHA Meyrick (1886: 281)

*A. pelodes* Meyrick (1883: 34); Gaede (1937: 555). New Hebrides. Marquesas Islands: Nuka Hiva, Tahuata. Type from Hawaii.

## Family EUCOSMIDAE

### LOBESIA Guénée

*L. peplotoma* Meyrick (1928*b*: 442). New Hebrides: Efate (Buxton).

### POLYCHROSIS Ragonot

*P. orthomorpha* Meyrick (1928*b*: 443). New Hebrides: Espiritu Santo, Efate (Buxton).

### CROCIDOSEMA Zeller

*C. plebeiana* Zeller (1847: 722). Society

Islands: Tahiti, Raiatea. Marquesas Islands: Nuka Hiva, Hiva Oa, Tahuata. Rapa Island ("St. George" Exped.). Larva on Malvaceae.

#### BACTRA Stephens

- B. truculenta** Meyrick (1909: 586). New Caledonia: Noumea (Catala, Barrau). Larva on *Cyperus rotundus*. Also in Fiji and Hawaii, introduced.
- B. litigatrix** Meyrick (1928a: 495). Society Islands: Tahiti ("St. George" Exped.).

#### EUCOSMA Hübner

- E. agriochlora** Meyrick (1928a: 495). Marquesas Islands: Nuka Hiva ("St. George" Exped.).
- E. chaomorpha** Meyrick (1928a: 495). Marquesas Islands: Nuka Hiva, Hiva Oa ("St. George" Exped.).

#### ACROCLITA Lederer

- Ac. physalodes** Meyrick (1910a: 368). Austral Islands: Rurutu ("St. George" Exped.).
- Ac. eocnephaea** Meyrick (1935b: 345). Marquesas Islands: Hiva Oa (l.c.).

#### ARGYROPLOCE Hübner

- A. rhynchias** Meyrick (1905: 586). Marquesas Islands: Hiva Oa, Tahuata. Society Islands: Tahiti, Raiatea. Austral Islands: Rurutu ("St. George" Exped.).
- A. aprobola** Meyrick (1926: 273). Rapa Island.
- A. eumenica** Meyrick (1928a: 496). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- A. isodoxa** Meyrick (1928b: 444). New Hebrides: Tanna (Buxton).

#### SPILONOTA Stephens

- S. thyelopsis** Meyrick (1926: 273). Rapa Island.
- S. dilacerata** Meyrick (1928a: 494). Austral Islands: Rurutu ("St. George" Exped.).
- S. holotephras** Meyrick (1924: 67). Marquesas Islands: Nuka Hiva, Hiva Oa, Tahuata ("St. George" Exped.). Type from Fiji.

#### Family TORTRICIDAE

NESOSCOPA Meyrick (1926: 271)

**N. exsors** Meyrick (1926: 74). Rapa Island.

#### DICHELOPA Lower

- D. honoranda** Meyrick (1926: 272). Rapa Island.
- D. sericopis** Meyrick (1926: 272). Rapa Island.
- D. deltozancla** Meyrick (1926: 272). Rapa Island.
- D. ceramocausta** Meyrick (1926: 272). Rapa Island (Meyrick, l.c., and "St. George" Exped.).
- D. iochorda** Meyrick (1926: 273). Rapa Island.
- D. exulcerata** Meyrick (1926: 273). Rapa Island (Meyrick, l.c., and "St. George" Exped.).
- D. pachydmeta** Meyrick (1928a: 493). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- D. argoschistes** Meyrick (1928a: 493). Society Islands: Tahiti ("St. George" Exped.).
- D. fulvistrigata** Meyrick (1928a: 494). Society Islands: Tahiti ("St. George" Exped.).
- D. peropaca** Meyrick (1928a: 494). Marquesas Islands: Nuka Hiva ("St. George" Exped.).
- D. choleranthes** Meyrick (1928a: 493). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- D. dryomorpha** Meyrick (1928a: 492). Marquesas Islands: Tahuata ("St. George" Exped.).
- D. praestrigata** Meyrick (1928a: 492). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- D. harmodes** Meyrick (1928a: 494). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- D. argosphena** Meyrick (1935b: 343). Marquesas Islands: Hiva Oa.
- D. pyrsogramma** Meyrick (1935b: 343). Marquesas Islands: Nuka Hiva.
- D. orthiostyla** Meyrick (1935b: 343). Marquesas Islands: Hiva Oa.



*D. porphyrophanes* Meyrick (1935*b*: 344). Marquesas Islands: Uapou, Hiva Oa.

*D. phalaranthes* Meyrick (1935*b*: 344). Marquesas Islands: Hiva Oa.

*D. cirrhodoris* Meyrick (1935*b*: 344). Marquesas Islands: Hiva Oa.

*D. castanopis* Meyrick (1935*b*: 345). Marquesas Islands: Hiva Oa, Uapou.

*XENOTHICTIS* Meyrick (1910: 279)

*X. paragona* Meyrick (1910*b*: 280). Loyalty Islands: Lifu.

*X. semiota* Meyrick (1910*b*: 280). Loyalty Islands: Lifu.

#### Family LIMACODIDAE

*MIRESA* Walker

*M. alma* Druce (1898: 215). New Caledonia.

*M. sobrina* Druce (1898: 214). New Caledonia.

#### Family PYRALIDIDAE

Subfamily PHYCITINAE

*ASPITHRA* Ragonot

*A. maculicostella* Ragonot (1888: 37). Marquesas Islands: Nuka Hiva, Hiva Oa, Tahuata.

*A. chrysur* Meyrick (1929*a*: 158). Marquesas Islands: Nuka Hiva, Hiva Oa ("St. George" Exped.).

*A. dryinandra* Meyrick (1929*a*: 157). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*A. denticornis* Meyrick (1929*a*: 156). Marquesas Islands: Hiva Oa, Fatu Hiva ("St. George" Exped.).

*PHYCITA* Curtis

*P. orthoclina* Meyrick (1929*a*: 158). Marquesas Islands: Hiva Oa, Nuka Hiva, Tahuata ("St. George" Exped.).

*ETIELLA* Zeller

*E. drososcia* Meyrick (1929*a*: 158). Society Islands: Tahiti ("St. George" Exped.).

*HOMOEOSOMA* Curtis

*H. inexplorata* Meyrick (1929*a*: 158). Society Islands: Tahiti. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.).

*CTENOMERISTIS* Meyrick (1929*a*: 159)

*Ct. ochrodepta* Meyrick (1929*a*: 159). Marquesas Islands: Hiva Oa, Nuka Hiva ("St. George" Exped.).

*CATEREMMA* Meyrick

*C. albicostalis* Walker (1865: 1258). Marquesas Islands: Nuka Hiva ("St. George" Exped.).

*C. halmophila* Meyrick (1929*a*: 159). Marquesas Islands: Hiva Oa, Tahuata, Fatu Hiva ("St. George" Exped.).

*ACROBASIS* Zeller

*A. ptilophanes* Meyrick (1929*a*: 160). Society Islands: Tahiti ("St. George" Exped.).

*EURHODOPE* Hübner

*E. ardescens* Meyrick (1929*a*: 160). Society Islands: Tahiti, Raiatea. Austral Islands: Rurutu ("St. George" Exped.).

#### Subfamily SCOPARIINAE

*SCOPARIA* Haworth

*S. chrysomicta* Meyrick (1929*a*: 166); Klima (1937: 43). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*S. chrysopetra* Meyrick (1929*a*: 169); Klima (1937: 43). Society Islands: Tahiti ("St. George" Exped.).

*S. citrocospa* Meyrick (1929*a*: 166); Klima (1937: 43). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*S. clerica* Meyrick (1929*a*: 167); Klima (1937: 43). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*S. commercialis* Meyrick (1929*a*: 167); Klima (1937: 43). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*S. officialis* Meyrick (1929*a*: 168); Klima (1937: 44). Marquesas Islands: Hiva Oa ("St. George" Exped.).

*S. opostactis* Meyrick (1929*a*: 168); Klima (1937: 44). Marquesas Islands: Fatu Hiva ("St. George" Exped.).

*S. philorhpha* Meyrick (1929*a*: 168); Klima (1937: 45). Society Islands: Tahiti ("St. George" Exped.).

*S. spectacularis* Meyrick (1929a: 167); Klima (1937: 45). Marquesas Islands: Hiva Oa ("St. George" Exped.).

DARYSCOPA Meyrick

*D. polysemalis* Hampson (1897: 239); Klima (1937: 56). Loyalty Islands: Lifu.

Subfamily NYMPHULINAE

CATACLYSTA Hübner

*C. blandialis* Walker (1859: 448); Klima (1937: 96). New Caledonia: Voh (Catala).

DRACAENURA Meyrick (1886a: 227)

*D. myota* Meyrick (1886a: 230); Klima (1937: 135). New Hebrides. Also in Fiji.

*D. leucoprocta* Hampson (1897: 193); Klima (1937: 135). New Hebrides (Mathew).

*D. cincticorpus* Hampson (1897: 194); Klima (1937: 136). Loyalty Islands.

PHYTHAGOREA Meyrick (1929a: 162)

*P. categorica* Meyrick (1929a: 162); Klima (1937: 136). Society Islands: Tahiti ("St. George" Exped.).

AULACODES Guénée

*A. secutalis* Walker (1865: 1291); Klima (1937: 143). New Hebrides.

*A. eupselias* Meyrick (1929a: 161); Klima (1937: 143). Marquesas Islands: Tahuata ("St. George" Exped.).

DECTICOGASTER Snellen

*D. biannulalis* Walker (1865: 1439); Klima (1937: 146). New Hebrides.

*D. vibrata* Meyrick (1929a: 161); Klima (1937: 148). Marquesas Islands: Hiva Oa ("St. George" Exped.).

BRADINA Lederer

*B. rectiferalis* Walker (1862a: 126); Klima (1937: 154). New Caledonia (Walker): Voh (Catala). Loyalty Islands (Paris Museum, coll. Ragonot). New Hebrides.

*B. antisema* Meyrick (1886a: 263); Klima (1937: 155). New Hebrides.

*B. perlucidalis* Hampson (1897: 201); Klima (1937: 155). Marquesas Islands: Taou Ata (J. J. Walker).

*B. tormentifera* Meyrick (1929a: 161); Klima (1937: 156). Marquesas Islands ("St. George" Exped.).

PILETOCERA Lederer

*P. signiferalis* Wallengren (1860: 175); Klima (1937: 175). Marquesas Islands. Society Islands: Tahiti.

*P. ochrosema* Meyrick (1886a: 247); Klima (1937: 176). New Hebrides. Also in Fiji.

Subfamily PYRAUSTINAE

REHIMENA Walker

*R. cissiphora* Turner (1908: 88); Klima (1939: 29). New Hebrides.

HYMENIA Hübner

*H. recurvalis* Fabricius (1775: 644); Klima (1939: 31) (= *Zinckenia fascialis* Cr.). New Caledonia: Noumea (Catala). New Hebrides. Society Islands: Tahiti. Marquesas Islands: Tahuata. Rapa Island ("St. George" Exped.).

EURRHYPARODES Snellen

*Eu. bracteolalis* Zeller (1852a: 30); Klima (1939: 36). New Hebrides.

*Eu. tricoloralis* Zeller (1852a: 31); Klima (1939: 425). Austral Islands: Rurutu ("St. George" Exped.).

ERCTA Walker

*E. ornatalis* Duponchel (1831: 207); Hampson (1898: 37); Klima (1939: 57). New Hebrides. Society Islands: Tahiti.

*E. chalybitis* Meyrick (1885: 444); Hampson (1898: 637); Klima (1939: 59). New Hebrides.

CNAPHALOCROCIS Lederer

*C. medinalis* Guénée (1854: 201); Hampson (1898: 638); Klima (1939: 61). New Caledonia. New Hebrides.

MARASMIA Lederer

*M. venialis* Walker (1859: 373); Hampson (1898: 639); Klima (1939: 65). Society Islands: Tahiti, Bora Bora. Marquesas Islands: Hiva Oa, Fatu Hiva, Nuka Hiva, Tahuata ("St. George" Exped.).



- M. trapezalis* Guénée (1854: 200); Hampson (1898: 639); Klima (1939: 65). Society Islands: Tahiti, Bora Bora, Raiatea. Austral Islands: Rurutu ("St. George" Exped.).
- M. hemicrossa* Meyrick (1886a: 217); Hampson (1898: 639); Klima (1939: 65). Society Islands: Tahiti, Moorea, Rapa Island.

## SYNGAMIA Guénée

- S. floralis* Zeller (1852a: 60); Hampson (1898: 644); Klima (1939: 71). New Hebrides (Hampson, l.c.). Society Islands: Tahiti (Meyrick, 1886a).
- S. calidalis* Guénée (1854: 294); Hampson (1898: 644); Klima (1939: 71). New Hebrides.

## CAPRINIA Walker

- C. mysteris* Meyrick (1886a: 233); Klima (1939: 110). New Hebrides.

## LAMPROSEMA Hübner

- L. diemenalis* Guénée (1854: 203); Hampson (1898: 699); Klima (1939: 162). New Hebrides (Hampson, l.c.). Society Islands: Tahiti, Bora Bora, Raiatea. Austral Islands: Rurutu ("St. George" Exped.).
- L. octasema* Meyrick (1886a: 259); Hampson (1898: 703); Klima (1939: 162). New Hebrides (Hampson, l.c.). New Caledonia (Catala). Parasite of banana. Also in Fiji.

## SYLEPTA Hübner

- S. derogata* Fabricius (1775: 641); Klima (1939: 193). New Hebrides. Also in Fiji.

## LYGROPIA Lederer

- L. erixantha* Meyrick (1886a: 258); Hampson (1898: 728); Klima (1939: 250). New Hebrides.

## DIAPHANIA Hübner

- D. indica* Saunders (1851: 163); Hampson (1898: 738); Klima (1939: 239). New Caledonia: Voh (Catala). Society Islands: Tahiti (Hampson, l.c.; Vesco). Marquesas Islands: Taio Hae (Delmas).
- D. glauculalis* Guénée (1854: 306); Hampson (1898: 741); Klima (1939: 243). New Hebrides.

- D. actorionalis* Walker (1859: 498); Hampson (1898: 742); Klima (1939: 245). New Hebrides.

- D. laticostalis* Guénée (1854: 303); Hampson (1898: 732); Klima (1939: 247). New Hebrides.

- D. incurvata* Warren (1896b: 116); Hampson (1898: 730); Klima (1939: 252). Loyalty Islands: Lifu.

- D. deliciosa* Butler (1887b: 114); Hampson (1898: 742); Klima (1939: 257). New Hebrides. New Caledonia (Paris Museum, coll. Ragonot).

- D. excelsalis* Walker (1865: 1360); Hampson (1898: 742); Klima (1939: 257). Loyalty Islands (Paris Museum, coll. Ragonot): Lifu (Hampson, l.c.).

- D. eurytusalis* Walker (1859: 503); Hampson (1898: 743); Klima (1939: 259). Loyalty Islands (Hampson, l.c.; Paris Museum, coll. Ragonot).

- D. stolalis* Guénée (1854: 293, III, 11); Hampson (1898: 744); Klima (1939: 260). New Hebrides.

- D. oceanitis* Meyrick (1886a: 222); Hampson (1898: 741); Klima (1939: 269). New Hebrides.

- D. talangalis* Hampson (1898: 761, L, 15); Klima (1939: 271). Loyalty Islands: Lifu.

- D. multilinealis* Kenrick (1907: 83, IV, 173); Klima (1939: 273). New Hebrides. Also in Fiji and Samoa.

- D. euthalassa* Meyrick (1935b: 338); Klima (1939: 272). Marquesas Islands: Hiva Oa.

- D. phormingopa* Meyrick (1935b: 339); Klima (1939: 273). Marquesas Islands: Hiva Oa.

- D. uranoptris* Meyrick (1929a: 163); Klima (1939: 273). Society Islands: Tahiti ("St. George" Exped.).

- D. psammocyma* Meyrick (1929a: 163); Klima (1939: 273). Society Islands: Tahiti ("St. George" Exped.).

## CHRY SOPHYLLIS Meyrick (1935b: 337)

- Ch. lucivaga* Meyrick (1935b: 338); Klima (1939: 287). Marquesas Islands: Hiva Oa.

## TALANGA Moore

- T. sexpunctalis* Moore (1877: 616, LX, 12); Klima (1939: 288). New Caledonia: Baraoua (Catala). New Hebrides.

## OEBIA Hübner

- O. undalis* Fabricius (1794: 226); Hampson (1898: 760, 87); Klima (1939: 309). In every island of the Pacific (Klima, l.c.).  
*O. cleoropa* Meyrick (1935b: 340); Klima (1939: 312). Marquesas Islands: Hiva Oa.

## EPIPAGIS Hübner

- E. cancellalis* Zeller (1852a: 34); Klima (1939: 314). New Caledonia: Baraoua (Catala).

## ARCHERNIS Meyrick

- A. subfulvalis* Klima (1939: 325). Society Islands.

## TERASTIA Guénée

- T. meticulousalis* Guénée (1854: 212); Klima (1939: 326). New Hebrides.

## ISCHNURGES Lederer

- I. octoguttalis* Felder and Rogenhofer (1874: 4); Hampson (1898: 179); Klima (1939: 351). Loyalty Islands. Society Islands: Tahiti.

## MARUCA Walker

- M. testulalis* Hübner and Geyer (1832: 12, fig. 629). New Caledonia: Voh (Catala). Marquesas Islands: Hiva Oa, Tahuata, Nuka Hiva, Fatu Hiva. Society Islands: Tahiti, Moorea, Raiatea. Austral Islands: Rurutu ("St. George" Exped.).

## DIASEMA Hübner

- D. ramburialis* Duponchel (1831: 343). Society Islands: Tahiti. Austral Islands: Rurutu ("St. George" Exped.).

## PACHYZANCLA Meyrick

- P. stultalis* Walker (1859: 669). Marquesas Islands: Hiva Oa ("St. George" Exped.).

## PSARA Snellen

- Ps. licarsisalis* Walker (1859: 686). Society Islands: Tahiti, Raiatea. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.).

## MECYNA Doubleday

- M. aureolalis* Lederer (1863: 473). Society Islands: Tahiti ("St. George" Exped.).

## CALAMOCHROUS Lederer

- C. thermochra* Meyrick (1929a: 165). Society Islands: Tahiti ("St. George" Exped.).

## IDIOBLASTA Warren

- I. lacteata* Warren (1891: 62). Marquesas Islands: Nuka Hiva ("St. George" Exped.).  
*I. straminata* Warren (1891: 62). Marquesas Islands: Hiva Oa ("St. George" Exped.).

## ISOCENTRIS Meyrick

- Is. illectalis* Walker (1859: 362). Rapa Island ("St. George" Exped.).

## PYRAUSTA Schrank

- P. phthorosticata* Meyrick (1929a: 166). Marquesas Islands: Hiva Oa ("St. George" Exped.).

## Subfamily PYRALINAE

## ENDOTRICHA Zeller

- E. mesenterialis* Walker (1859: 285). Society Islands: Tahiti. Austral Islands: Rurutu ("St. George" Exped.).

## HERCULIA Walker

- H. repetita* Butler (1887b: 115). Society Islands: Tahiti ("St. George" Exped.).

## Subfamily GALLERIINAE

## MELIPHORA Guénée

- M. grisella* Fabricius (1794: 289). Society Islands: Tahiti ("St. George" Exped.).

## APHOMIA Hübner

- A. sociella* Linné (1758: 534). New Caledonia: Baraoua (Catala).

## TIRATHABA Walker

- T. rufivena* Walker (1866: 1956). New Caledonia. New Hebrides. Parasite of the cotton tree (Risbec, 1942).

## COLEONEURA Ragonot

- C. trichogramma* Meyrick (1886a: 273). New Hebrides (Risbec, 1942). Type from Fiji.



## Family PTEROPHORIDAE

## SPHENARCHES Meyrick

*S. caffer* Zeller (1852*b*: 348); Meyrick (1913: 5). New Hebrides.

## ALUCITA Linné

*A. aptalis* Walker (1864*b*: 950); Meyrick (1913: 17). New Hebrides.

## MARASMARCHA Meyrick

*M. pumilio* Zeller (1873: 324); Meyrick (1913: 28). Marquesas Islands: Nuka Hiva, Hiva Oa, Tahuata, Fatu Hiva. Society Islands: Tahiti. Austral Islands: Rurutu ("St. George" Exped.).

## Family THYRIDIDAE

## HYPOLAMPRUS Hampson

*H. squalida* Warren (1908: 337); Dalla Torre (1924: 16). Loyalty Islands: Lifu.

## Family SPHINGIDAE

## Subfamily ACHERONTIINAE

## HERSE Oken

*H. convolvuli* Linné (1758: 490); Wagner (1913: 7). Society Islands: Tahiti.

*H. fasciatus* Rothschild (1894: 94); Wagner (1913: 5). Loyalty Islands: Lifu.

## PSILIGRAMMA Rothschild and Jordan

*P. menephron* Cramer (1780: 164); Wagner (1913: 25).

subsp. *lifuense* Rothschild (1894: 90). New Caledonia (Wagner): Noumea (Quod). New Hebrides (Mrs. Pruvot). Loyalty Islands: Lifu (Rothschild).

## Subfamily SESIINAE

## CEPHONODES Hübner

*C. janus* Miskin (1891: 6); Wagner (1914: 216).

subsp. *simplex* Rothschild (1894: 86). Loyalty Islands: Lifu.

*C. lifuensis* Rothschild (1894: 66). New Caledonia: Noumea (Quod). Loyalty Islands: Lifu.

*C. novebudensis* Clark (1927: 106). New Hebrides.

## Subfamily PHILAMPELINAE

## CHROMIS Hübner

*Ch. erotus* Cramer (1777: 12, CIV, B); Wagner (1915: 232). New Caledonia (Marie): Noumea (Quod, Risbec). New Hebrides (Mrs. Pruvot): Vaté, Port Vila (Risbec). Society Islands (J. J. Walker, 1883; Paris Museum, coll. de Joannis; "St. George" Exped.): Bora Bora ("St. George" Exped.). Marquesas Islands: Taiohae (Delmas), Hiva Oa, Nuka Hiva, Tahuata ("St. George" Exped.; Collenette, 1935). Archipelago of the Tuamotus: Napuka. Austral Islands: Rurutu ("St. George" Exped.).

## DEILEPHILA Laspeyres

*D. placida* Walker (1856*b*: 186); Wagner (1915: 239).

subsp. *torenia* Druce (1882: 16). Loyalty Islands: Lifu. New Hebrides: Espiritu Santo (Risbec).

## MACROGLOSSUM Scopoli

*M. hirundo* Boisduval (1832: 184); Wagner (1915: 296).

subsp. *typ.* Society Islands: Tahiti (Dumont d'Urville in coll. Paris Museum; Challier; "St. George" Exped.).

subsp. *confluens* Rothschild and Jordan (1906: 407). New Hebrides (Wagner): Vaté, Port Vila (Risbec).

subsp. *lifuensis* Rothschild (1894: 67). New Caledonia. Loyalty Islands: Lifu (Wagner).

*M. corythus* Walker (1856*b*: 92); Wagner (1915: 299).

subsp. *novebudensis* Clark (1926: 54). New Hebrides.

subsp. *fuscicauda* Rothschild and Jordan (1903: 663). Loyalty Islands: Lifu.

*M. moluccensis* Rothschild (1894: 67). Loyalty Islands: Lifu. Might really be *M. corythus* Wlk.

*M. marquesanum* Collenette (1935: 209). Marquesas Islands: Hiva Oa (Le Bronnec).

## HIPNOTION Hübner

- H. velox** Fabricius (1793: 378); Wagner (1919: 376) (= *Panacra griseola* Rothschild = *P. lifuensis* Rothschild. = *P. rosea* Rothschild.). New Caledonia (Millot; Paris Museum, coll. de Joannis). Loyalty Islands: Lifu (Rothschild).
- H. celerio** Linné (1758: 491); Wagner (1919: 377). New Caledonia: Noumea (Quod), Païta (Antonino), Western Coast (Risbec). New Hebrides: Vanuatu, Port Vila; Mallicolo (Risbec). Society Islands: Tahiti (J. J. Walker, 1883).

## THERETRA Hübner

- T. nesus** Drury (1773: 46); Wagner (1919: 388). New Caledonia: Noumea (Quod).
- T. clotho** Drury (1773: 48); Wagner (1919: 390). Loyalty Islands: Lifu.
- T. silherensis** Walker (1856b: 143); Wagner (1919: 401). New Hebrides (Mrs. Pruvot).

## Family GEOMETRIDAE

## Subfamily BOARMINAE

## CLEORA Curtis

- C. hemiopa** Prout (1928: 160). New Hebrides (Prout, l.c.).
- C. decisaria** Walker (1866: 1589).  
subsp. *quirosi* Prout (1929b: 207). New Hebrides ("St. George" Exped.).  
subsp. *ecdees* Prout (1929b: 207). Loyalty Islands: Lifu (Tring Museum).
- C. psychastis** Meyrick (1886a: 211). New Hebrides.
- C. immemorata** Walker (1862b: 1540). Loyalty Islands: Lifu (Butler, 1877). New Caledonia.
- C. collenettei** Prout (1929c: 255). Marquesas Islands: Hiva Oa, Fatu Hiva, Tahuata, Nuka Hiva ("St. George" Exped.).
- C. esoterica** Prout (1929c: 255). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- C. myrmidonaria** Guénée (1857a: 271). Society Islands: Tahiti ("St. George" Exped.).
- C. cheesmanae** Prout (1929b: 217). New Hebrides (Prout, l.c.).

- C. stenoglypta** Prout (1929a: 272). Rapa Island ("St. George" Exped.).
- C. dodonaeae** Prout (1929a: 273). Rapa Island ("St. George" Exped.).
- C. leucostigma** Prout (1929a: 276). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- C. licornaria** Guénée (1857a: 285). Society Islands: Tahiti, Moorea (J. J. Walker in Prout, 1929a).

## BOARMIA Treitschke

- B. lichenina** Butler (1877: 358). Loyalty Islands: Lifu.

## FELICIA Thierry-Mieg (1915: 40)

- F. caledonica** Thierry-Mieg (1915: 40). New Caledonia.

## Subfamily LARENTIINAE

## CRETHEIS Meyrick (1886a: 192)

- Cr. cymatodes** Meyrick (1886a: 193). New Hebrides.

## CHLOROCYSTIS Hübner

- C. lepta** Meyrick (1886a: 191). Society Islands: Tahiti, Moorea ("St. George" Exped.).
- C. torninubia** Prout (1929a: 267). Marquesas Islands: Hiva Oa ("St. George" Exped.).
- C. coloptilia** Prout (1929a: 268). Marquesas Islands: Hiva Oa, Nuka Hiva ("St. George" Exped.).
- C. abundata** Prout (1929a: 269). Marquesas Islands: Hiva Oa ("St. George" Exped.).

## GYMNOSCELIS Mabilie

- G. imparalilis** Walker (1865: 1416). Marquesas Islands: Hiva Oa, Nuka Hiva. Society Islands: Tahiti, Raiatea ("St. George" Exped.).
- G. erymna** Meyrick (1886a: 192). Society Islands: Tahiti, Raiatea. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.).

## Subfamily OENOCHROMINAE

## EUMELEA Duncan

- E. degener** Warren (1894: 375); Prout (1912: 53). Loyalty Islands: Lifu.



## OZONA Walker

- O. acrophaea* Meyrick (1886*a*: 199); Prout (1912: 73). New Hebrides.  
*O. hesperias* Meyrick (1886*a*: 196); Prout (1912: 74). New Hebrides.

## DESMOBATHRA Meyrick

- D. plana* Warren (1894: 380); Prout (1912: 75). New Caledonia (Paris Museum, coll. Thierry-Mieg). Loyalty Islands: Lifu.

## Subfamily HEMITHEINAE

## THALASSODES Guénée

- T. chloropis* Meyrick (1886*a*: 204); Prout (1913: 96). New Hebrides (Risbec).  
*T. pilaria* Guénée (1857*a*: 361); Prout (1913: 97). Society Islands: Tahiti. Bora Bora ("St. George" Exped.).

## PRASINOCYMA Warren

- P. albicosta* Walker (1860: 529); Prout (1913: 98). Loyalty Islands.

PYRRHORACHIS Warren (1896*a*: 292)

- Py. viridula* Warren (1903: 363); Prout (1913: 162). Loyalty Islands: Lifu.

## Subfamily STERRHINAE

## ANISODES Guénée

- A. decolorata* Warren (1897*b*: 215); Prout (1934: 109). Loyalty Islands: Lifu (Prout, l.c.). Society Islands: Tahiti. Archipelago of the Tuamotus: Fakarava ("St. George" Exped.).  
*A. samoana* Warren (1897*b*: 226) (= *A. parallela* Warren, 1897*b*: 226); Prout (1934: 119). New Hebrides. Loyalty Islands: Lifu (Prout, l.c.).  
*A. oblivaria* Walker (1861: 643); Prout (1934: 119). From Ceylon to the Samoan Islands (Prout, l.c.).

## SCOPULA Schrank

- S. oppilata* Walker (1861: 776); Prout (1934: 260). Loyalty Islands.  
*S. homodoxa* Meyrick (1886*a*: 208); Prout (1934: 267). Loyalty Islands: Lifu.

- S. undilinea* Warren (1900: 105); Prout (1934: 270). Loyalty Islands: Lifu.

- S. oxystoma* Prout (1929*a*: 266). Marquesas Islands: Hiva Oa ("St. George" Exped.).

- S. tersicallis* Prout (1929*a*: 267). Marquesas Islands: Hiva Oa ("St. George" Exped.).

## STERRHA Hübner

- St. rhipistis* Meyrick (1886*a*: 205); Prout (1934: 426). New Hebrides.

## BURSADA Walker

- B. fulvinaeata* Warren (1895: 121). New Caledonia (Germain). Loyalty Islands: Lifu (Paris Museum, coll. Thierry-Mieg).

## Family URANIIDAE

## NYCTALEMON Dalman

- N. curvata* Skinner (1903: 298); Dalla Torre (1924: 8). New Hebrides (Skinner, l.c.; Aubert de la Rüe; Kowalski).

## Family EPIPLEMIDAE

## DIRADES Walker

- D. latibrunnea* Warren (1896*c*: 346); Dalla Torre (1924: 30). Loyalty Islands: Lifu.

## Family AMATIDAE

## EUCHROMIA Hübner

- E. creusa* Linné (1758: 494); Zerny (1912: 89). New Caledonia (Marie). New Hebrides (Zerny, l.c.).  
*E. rubricollis* Walker (1864*b*: 99); Zerny (1912: 90). Loyalty Islands: Lifu (Zerny, l.c.). New Hebrides: Vaté, Port Vila (Kowalski).

## Family LITHOSIIDAE

## Subfamily NOLIINAE

## CELAMA Walker

- C. insularum* Collenette (1928: 469). Society Islands: Tahiti. Rapa Island ("St. George" Exped.).

## Subfamily LITHOSIINAE

## OENISTIS Hübner

- O. entella* Cramer (1779: pl. 208, fig. D); Strand (1922: 598).

subsp. *delia* Fabricius (1787*a*: 140). New Hebrides.

#### HELIOSIA Hampson

*H. atriplaga* Hampson (1914: 586); Strand (1922: 658). Loyalty Islands.

#### LAMBULA Walker

*L. erema* Collenette (1935: 202). Marquesas Islands: Hiva Oa (Le Bronnec).

#### Subfamily ARCTIINAE

##### ARDICES Walker

*A. glatignyi* Le Guillou (1841: 257); Strand (1919: 159). New Hebrides.

##### DIACRISIA Hübner

*D. lifuense* Rothschild (1910*a*: 122); Strand (1919: 185). New Caledonia (Quod, Catala). Loyalty Islands: Lifu.

##### UTETHEISA Hübner

*U. lotrix* Cramer (1777: pl. 109, figs. E and F); Strand (1919: 361).

subsp. *salomonis* Rothschild (1910*b*: 181). New Hebrides: Tanna (Aubert de la Rüe), Mallicolo (Risbec).

subsp. *stigmata* Rothschild (1910*b*: 182). New Caledonia: Noumea (Antonino, Joly, Risbec, Catala), Paita (Antonino), Mt. Mou (Quod), Western Coast (Risbec). Loyalty Islands.

*U. pulchella* Linné (1758: 534); Strand (1919: 361). New Hebrides. Gambier Islands (Seurat).

##### RHODOGASTRIA Hübner

*R. albivitra* Hampson (1901: 502); Strand (1919: 373). New Caledonia: Noumea (Marie, coll. Paris Museum). Loyalty Islands: Lifu (Mrs. Pruvot).

#### Subfamily NYCTEMERINAE

##### NYCTEMERA Hübner

*N. baulus* Boisduval (1832: 200); Bryk (1937: 54). New Caledonia: Noumea (Risbec), Paita (Antonino).

*N. extendens* Walker (1856*a*: 1666); Bryk (1937: 62). New Hebrides.

#### Subfamily AGANAINAE

##### AGAPE Felder and Rogenhofer

*A. leonina* Butler (1879: 161); Gaede (1932: 2). Loyalty Islands: Lifu. New Hebrides: Mallicolo (Risbec).

##### NEOCHERA Hübner

*N. contraria* Reich (1936: 419). New Hebrides.

##### ASOTA Hübner

*A. alienata* Walker (1864*b*: 46); Gaede (1932: 12). New Hebrides: Vaté, Port Vila (Mrs. Pruvot), Mallicolo (Risbec).

*A. caricae* Fabricius (1775: 596); Gaede (1932: 13). New Hebrides (Mrs. Pruvot): Vaté, Port Vila (Risbec, Kowalski).

#### Family NOCTUIDAE

##### Subfamily AGROTINAE

##### CHLORIDEA Westwood

*C. armigera* Hübner (1802–1808: pl. 79, fig. 370); Hampson (1903: No. 56). New Caledonia (Vayssière, Risbec, Catala). Harmful to cotton and tobacco.

*C. assulta* Guénée (1852*b*: 178); Hampson (1903: No. 57). Society Islands: Tahiti (Hampson, l.c.; Collenette, 1928).

##### EUXOA Hübner

*E. radians* Guénée (1852*a*: 261); Hampson (1903: No. 285). New Caledonia (Paris Museum, coll. Thierry-Mieg).

*E. infusa* Boisduval (1832: 240); Hampson (1903: No. 286). New Hebrides: Aneiteum (Hampson, l.c.).

*E. fumipennis* Warren (1912: 5). Loyalty Islands: Lifu.

##### AGROTIS Hübner

*A. ypsilon* Rottemburg (1776: 141); Hampson (1903: No. 646). New Caledonia: Voh (Catala).

*A. compta* Walker (1856*b*: 404); Hampson (1903: No. 702). New Hebrides.



## Subfamily HADENINAE

## TIRACOLA Moore

- T. plagiata* Walker (1857: 740); Hampson (1905: No. 1494). Society Islands: Tahiti. Marquesas Islands: Nuka Hiva (Hampson, "St. George" Exped., and Collenette, 1935).

## Subfamily CUCULLIINAE

## EUMICHTIS Hübner

- E. extima* Walker (1857: 875); Hampson (1906: No. 2514). New Caledonia (Paris Museum, coll. Thierry-Mieg).

## Subfamily ZENOBIINAE

## ERIOPIUS Treitschke

- E. maillardi* Guénée (1862: 39); Hampson (1908: No. 3417). New Hebrides (Mathew).  
*E. reticulata* Pagenstecher (1884: 226; VI, 7); Hampson (1908: No. 3424). New Hebrides (Mathew).  
*E. meridionalis* Collenette (1928: 471). Rapa Island ("St. George" Exped.). New Hebrides.  
*E. ouria* Collenette (1928: 472). Marquesas Islands: Hiva Oa, Fatu Hiva ("St. George" Exped.).

## CALOGRAMMA Guénée

- C. festiva* Donovan (1805: pl. 36); Hampson (1909: No. 3857). New Caledonia (coll. Paris Museum): Noumea (Catala). New Hebrides (Mrs. Pruvot).

## PRODENIA Guénée

- P. litura* Fabricius (1775: 601); Hampson (1909: No. 3862). Society Islands (J. J. Walker): Tahiti (Mathew and "St. George" Exped.), Raiatea ("St. George" Exped.). Marquesas Islands (J. J. Walker): Hiva Oa, Fatu Hiva, Tahuata, Nuka Hiva. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.). New Caledonia (Risbec, 1942), Baraoua (Catala). Harmful to cotton and tobacco.

## SPODOPTERA Guénée

- S. mauritia* Boisduval (1883: 92; XIII, 9); Hampson (1909: No. 3871). Society Is-

lands: Tahiti (J. J. Walker and "St. George" Exped.), Raiatea. Marquesas Islands: Nuka Hiva. Rapa Island ("St. George" Exped.).

## PERIGEA Guénée

- P. serva* Walker (1858: 1689). Marquesas Islands: Hiva Oa. Society Islands: Tahiti, Raiatea ("St. George" Exped.). Larva on *Piper*.

## ELYDNA Walker

- E. nonagricola* Walker (1864a: 166). Loyalty Islands (coll. Paris Museum). Society Islands: Tahiti. Rapa Island ("St. George" Exped.).

## CHASMINA Walker

- C. sericea* Hampson (1893: 92); Hampson (1910a: No. 4794). New Caledonia (Paris Museum, coll. Thierry-Mieg).  
*C. tibialis* Fabricius (1775: 578); Hampson (1910a: No. 4796). New Caledonia: Noumea (Antonino), Canala (Delacour). Society Islands: Tahiti (J. J. Walker, Mathew, "St. George" Exped.). Rapa Island ("St. George" Exped.).

## Subfamily ERASTRIINAE

## EUBLEMMA Hübner

- E. quadrilineata* Moore (1881: 370, XXXVIII, 14); Hampson (1910b: No. 5095). New Hebrides (Mathew).  
*E. rivula* Moore (1882: 140); Hampson (1910b: No. 5182). Society Islands: Tahiti, Raiatea, Bora Bora ("St. George" Exped.).

## AMYNA Guénée

- A. natalis* Walker (1858: 214); Hampson (1910b: No. 5704). Rapa Island ("St. George" Exped.).  
*A. octo* Guénée (1852a: 233); Hampson (1910b: No. 5713). Marquesas Islands (J. J. Walker, Mathew): Fatu Hiva, Tahuata, Nuka Hiva ("St. George" Exped.). Society Islands (J. J. Walker): Tahiti, Bora Bora ("St. George" Exped.). New Hebrides (Mathew).

- A. punctum** Fabricius (1794: 34); Hampson (1910*b*: No. 5718). New Hebrides (Mathew).

EUSTROTIA Hübner

- E. ritsemae** Snellen (1880*a*: 57); Hampson (1910*b*: No. 5878). Society Islands: Tahiti (J. J. Walker, Mathew, Nicoll, "St. George" Exped.), Raiatea. Austral Islands: Rurutu ("St. George" Exped.).

Subfamily EUTELIINAE

BOMBOTELIA Hampson

- B. jocosatrix** Guénée (1852*b*: 304); Hampson (1912: No. 6206). New Caledonia: Noumea (Catala).

PHLEGETONIA Guénée

- P. carbo** Guénée (1852*b*: 302); Hampson (1912: No. 6278). New Caledonia. Loyalty Islands: Lifu, Maré (coll. Paris Museum).  
**P. delatrix** Guénée (1852*b*: 304); Hampson (1912: No. 6295). Society Islands: Raiatea. Rapa Island ("St. George" Exped.).

Subfamily STICTOPTERINAE

LOPHOPTERA Guénée

- L. squammigera** Guénée (1852*c*: 55); Hampson (1912: No. 6408). Loyalty Islands. New Hebrides (coll. Paris Museum).

GYRTONA Walker

- G. divitalis** Walker (1863: 91); Hampson (1912: No. 6474). Society Islands: Raiatea ("St. George" Exped.).

Subfamily SARROTHRIPINAE

BLENINA Walker

- B. donaus** Walker (1857: 1215); Hampson (1912: No. 6758). Loyalty Islands (Paris Museum, coll. Donckier). New Hebrides (Paris Museum, coll. de Joannis).

Subfamily WESTERMANNIINAE

EARIAS Hübner

- E. huegeli** Rogenhofer (1870: 872); Hampson (1912: No. 6862). New Caledonia: Noumea (Risbec, 1942; Catala; coll. Paris Museum).

New Hebrides: Espiritu Santo (Risbec). Society Islands: Tahiti (Nicoll, "St. George" Exped.), Raiatea, Bora Bora ("St. George" Exped.). Marquesas Islands: Fatu Hiva (J. J. Walker). Austral Islands: Rurutu ("St. George" Exped.).

XANTHODES Guénée

- X. transversa** Guénée (1852*b*: 211); Hampson (1912: No. 7112). New Hebrides (Mathew).

Subfamily CATOCALINAE

COCYTODES Guénée

- C. caerulea** Guénée (1852*c*: 41); Hampson (1913*a*: No. 7383). New Caledonia (Lyard): Puerihouen (Quod), Canala (Delacour), Baroua (Catala). Loyalty Islands (Whitmei). New Hebrides (Mathew).

PHYLLODES Boisduval

- P. imperialis** Druce (1888: 241); Hampson (1913*a*: No. 7500). New Caledonia (Milot). Loyalty Islands (Paris Museum, coll. de Joannis). New Hebrides (Hampson, l.c.; Mrs. Pruvot).

LAGOPTERA Hübner

- L. miniacea** Felder and Rogenhofer (1874: pl. 116, fig. 8); Hampson (1913*a*: No. 7527). New Hebrides: Tanna (Mrs. Pruvot), Mallicolo (Risbec). Also from Solomons and Fiji.

ANUA Walker

- A. coronata** Fabricius (1775: 596); Hampson (1913*a*: No. 7540). New Caledonia: Noumea (Paris Museum, coll. Fleutiaux). New Hebrides: Pentecôte Island (Mrs. Pruvot). Society Islands: Tahiti ("St. George" Exped.).

ACHAEA Hübner

- A. serva** Fabricius (1775: 593); Hampson (1913*a*: No. 7649). New Caledonia (Marie): Mt. Mou (Quod), Western Coast (Risbec). Loyalty Islands (Paris Museum, coll. Donckier): Lifu (Marshall). New Hebrides: Vaté (Turner).



**A. janata** Linné (1758: 527) (= *melicerta* Drury); Hampson (1913a: No. 7669). New Caledonia (Marie): Noumea (Risbec, Quod, Catala). New Hebrides (Mathew): Vaté, Port Vila (Kowalski). Society Islands: Tahiti (Mathew, Vesco, "St. George" Exped.). Marquesas Islands: Nuka Hiva (J. J. Walker), Tongatabu (Lister), Taiohae (Bedoc), Hiva Oa, Rapa Island ("St. George" Exped.). Gambier Islands: Taraourou Roa (Seurat). Larva on *Ricinus communis* L.

**A. pentasema** Prout (1919: 181). New Caledonia (Layard). Loyalty Islands: Uvea (coll. Joicey), Lifu (coll. British Museum).

**A. marquesanus** Collenette (1928: 476). Marquesas Islands: Hiva Oa ("St. George" Exped.).

#### PARALLELLIA Hübner

**P. redunca** Swinhoe (1900: 141); Hampson (1913a: No. 7687). New Hebrides (Paris Museum, coll. de Joannis).

**P. prisca** Walker (1858: 1385); Hampson (1913a: No. 7690). New Hebrides (Paris Museum, coll. de Joannis).

**P. joviana** Cramer (1782: 237); Hampson (1913a: No. 7711). Loyalty Islands: Lifu (Hampson, l.c.). New Hebrides (Paris Museum, coll. de Joannis).

#### GRAMMODES Guénée

**G. oculicola** Walker (1858: 1446); Hampson (1913b: No. 7778). New Caledonia: Noumea (Paris Museum, coll. Fleutiaux). Loyalty Islands: Lifu (coll. Paris Museum). Austral Islands: Rurutu ("St. George" Exped.).

#### CHALCIOPE Hübner

**C. cephise** Cramer (1779: 59); Hampson (1913b: No. 7794). New Hebrides: Mallicolo (Risbec).

#### HYPAETRA Guénée

**H. discolor** Fabricius (1794: 50); Hampson (1913b: No. 7832). Marquesas Islands: Hiva Oa, Fatu Hiva, Nuka Hiva, Tahuata ("St. George" Exped.). Society Islands: Tahiti, Moorea (J. J. Walker).

#### MOCIS Hübner

**M. frugalis** Fabricius (1775: 601); Hampson (1913b: No. 7857). New Caledonia (Marie): Canala (Delacour), Noumea, Voh (Catala). New Hebrides: Mallicolo (Risbec), Tanna (Aubert de la Rüe), Vaté, Port Vila (Risbec). Loyalty Islands (Paris Museum, coll. Donckier). Marquesas Islands: Fatu Hiva (Walker, "St. George" Exped.), Hiva Oa, Tahuata, Nuka Hiva ("St. George" Exped.). Society Islands: Tahiti (de la Garde, "St. George" Exped.), Bora Bora, Raiatea. Archipelago of the Tuamotus: Napuku. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.).

**M. trifasciata** Stephens (1829: 128); Hampson (1913b: No. 7861). New Caledonia: Canala (Delacour), Noumea (Catala). Marquesas Islands (Walker): Hiva Oa, Fatu Hiva, Tahuata, Nuka Hiva ("St. George" Exped.). Society Islands: Tahiti (J. J. Walker), Raiatea, Bora Bora. Austral Islands: Rurutu ("St. George" Exped.).

#### Subfamily PHYTOMETRINAE

##### PHYTOMETRA Haworth

**P. chalcites** Esper (1789: 441); Hampson (1913b: No. 8310). New Caledonia: Noumea (Quod, Risbec). Loyalty Islands (Paris Museum, coll. Donckier). Society Islands: Tahiti (Walker, Vesco, "St. George" Exped.), Raiatea ("St. George" Exped.). Marquesas Islands (J. J. Walker): Hiva Oa, Nuka Hiva. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.).

**P. albostriata** Bremer and Grey (1853: 18); Hampson (1913b: No. 8325). Rapa Island ("St. George" Exped.).  
Larva on *Erigeron bonariensis*.

#### Subfamily NOCTUINAE (= Ophiderinae)

##### ANONIS Hübner

**A. flava** Fabricius (1775: 601). Marquesas Islands: Hiva Oa, Nuka Hiva. Society Islands: Tahiti. Rapa Island ("St. George" Exped.).

*A. fulvida* Guénée (1852*b*: 397). New Hebrides (Risbec; Paris Museum, coll. de Joannis).

*A. vitiensis* Butler (1886: 408). Loyalty Islands (Paris Museum, coll. de Joannis). New Hebrides (Mrs. Pruvot). Society Islands: Tahiti (J. J. Walker, Mathew, "St. George" Exped.), Raiatea. Austral Islands: Rurutu. Rapa Island ("St. George" Exped.). Larva on *Hibiscus tiliaceus* L.

#### SERICIA Guénée

*S. layardi* Hampson (1926: 121). Loyalty Islands (Layard).

*S. feducia* Cramer (1777: pl. 6, fig. 3). New Caledonia (Marie): Noumea (Risbec).

#### POLYDESMATA Boisduval

*P. umbricola* Boisduval (1833: 108; XIII, 5). New Caledonia: Noumea (Risbec), Baraoua (Catala). New Hebrides (Kowalski): Ambryn (Mrs. Pruvot). Society Islands: Tahiti, Raiatea ("St. George" Exped.).

#### AEDIA Hübner

*A. sericea* Butler (1882: 230). Austral Islands: Rurutu ("St. George" Exped.).

#### LACERA Guénée

*L. alope* Cramer (1777: pl. 286). New Caledonia (Marie).

#### SERRODES Guénée

*S. inara* Cramer (1777: pl. 239). Loyalty Islands (Paris Museum, coll. Donckier). New Caledonia (Marie). New Hebrides (Paris Museum, coll. de Joannis).

#### OPHIDERES Boisduval

*O. salaminia* Fabricius (1775: 17). New Caledonia (Marie, Germain). New Hebrides: Vaté, Port Vila; Mallicolo (Risbec).

*O. fullonica* Linné (1758: 812). New Caledonia (Marie, Millot, Longuet): Noumea (Quod; Paris Museum, coll. Fleutiaux), Canala (Delacour). Loyalty Islands (Paris Museum, coll. Donckier). New Hebrides (Mrs. Pruvot; Paris Museum, coll. de Joannis):

Mallicolo (Risbec). Society Islands: Tahiti (Vesco).

*O. materna* Linné (1758: 840). New Caledonia (Marie).

#### ANTICARSIA Hübner

*A. irrorata* Fabricius (1787*a*: 506). Society Islands: Tahiti, Moorea, Raiatea. Rapa Island ("St. George" Exped.).

#### Subfamily HYPENINAE

##### SIMPLICIA Guénée

*S. caenensis* Walker (1858: 94). Marquesas Islands: Hiva Oa. Austral Islands: Rurutu. Society Islands: Tahiti (J. J. Walker, "St. George" Exped.).

##### HYDRILLODES Guénée

*H. melanozoma* Collenette (1928: 481). Rapa Island ("St. George" Exped.).

*H. crispipalpus* Collenette (1928: 482). Society Islands: Tahiti ("St. George" Exped.).

#### HYPENA Schrank

*H. walkeri* Collenette (1928: 482). Society Islands: Tahiti ("St. George" Exped.).

*H. longfieldae* Collenette (1928: 483). Marquesas Islands: Hiva Oa. Rapa Island ("St. George" Exped.).

*H. sanctigeorgii* Collenette (1928: 483). Marquesas Islands ("St. George" Exped.).

#### FAUTAUA Collenette (1928: 484)

*F. diagonalis* Collenette (1928: 484). Society Islands: Tahiti ("St. George" Exped.).

*F. innupta* Collenette (1928: 485). Society Islands: Tahiti ("St. George" Exped.).

#### LUCERIA Walker

*L. oculalis* Moore (1877: 614). Rapa Island ("St. George" Exped.).

#### Subfamily HYBLAEINAE

##### HYBLAEA Fabricius

*H. puera* Cramer (1777: 10). New Hebrides (Prout, 1919). Marquesas Islands: Hiva Oa ("St. George" Exped.).



## Family LYMANTRIIDAE

## EUPROCTIS Hübner

*E. dolichocera* Collenette (1938: 371). New Hebrides: Vaté, Port Vila (Kowalski).

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## Flora of Johnston Island, Central Pacific

F. R. FOSBERG<sup>1</sup>

THE FIRST LIST of plants of Johnston Island, published in 1931 by Christophersen (*Vascular Plants of Johnston and Wake Islands*. Bernice P. Bishop Mus. Occas. Papers 9(13): 1-20, 1931), was based on the collections of the Tanager Expedition in 1923. Three species were reported and a few notes on the vegetation were included. The three species were *Lepturus repens*, *Boerhavia diffusa*, and *Tribulus cistoides*. There is little doubt that these made up the whole vascular flora at the time, as Johnston is a very small, low, sandy, barren island and would not have been difficult to cover thoroughly. Few smaller floras are known (see Fosberg, F. R., *Vegetation of Vostok Island, Central Pacific*. Bernice P. Bishop Mus., Spec. Pub. 30: 19, 1937).

In the late 1930's aviation activities began to change the island. It became an important air base during the war and when I paid it a brief visit during 1946 there was apparently no original vegetation remaining, the whole island being occupied by runways and buildings with disturbed ground in the open places and along paths and roadsides. The plant most noticeable, though not most abundant at that time, was *Pluchea odorata*. Doubtless this had been brought from Honolulu, where it is common, but whether it was introduced accidentally or deliberately is not known to me. A number of other plants were noticed growing as ornamentals around the buildings.

On November 1, 1946, my brother, Kenneth P. Fosberg, made, at my request, a collection of all the plants that he could find during a day

spent on the island. Twenty-six species in all were collected, most of them in duplicate. A coconut seedling was seen but not collected. An almost complete set of plants was presented to the Bernice P. Bishop Museum in Honolulu. The remainder were sent to Washington, but were apparently lost in the mail.

The increase from 3 to 27 species consists mainly of species that are obvious introductions, either deliberate, as cultivated plants, or accidental, as weeds. Only two, *Messerschmidia argentea* and *Scaevola frutescens*, are species that might be expected to be native on an island such as Johnston, and they are both conspicuous enough so they could not possibly have been missed by the Tanager party if they had been present in 1923. The flora has thus been greatly enriched by human activity, and the original flora has maintained itself. This could be likely only in a pioneer habitat such as a dry coral island.

All the weeds as well as the planted species are common on Oahu, Hawaiian Islands. Whether the weed seeds came with nursery stock or by accidental adherence to plane or cargo is hard to know; but observations around other Pacific air bases suggest that the latter process is not negligible.

The list of species follows with such notes on occurrence as were provided by the collector. The general habitat for all is coral sand. Determinations are my own.

*Cenchrus echinatus* L. Abundant. K. P. Fosberg 7.

*Chloris inflata* Link. Abundant. K. P. Fosberg 11.

*Cynodon dactylon* (L.) Pers. One small patch seen. K. P. Fosberg 16.

<sup>1</sup> Research Associate, Pacific Vegetation Project, Catholic University of America, Washington, D. C. Manuscript received March 7, 1949.



- Eleusine indica* (L.) Gaertn. Rare. K. P. Fosberg 17.
- Lepturus repens* (Forst.) R. Br. Abundant. K. P. Fosberg 9.
- Setaria verticillata* Beauv. Common locally. K. P. Fosberg 26.
- Cocos nucifera* L. One seedling seen.
- Casuarina equisetifolia* L. Commonly planted. K. P. Fosberg 20.
- Boerhavia diffusa* L. Abundant, especially in places not walked on too much. K. P. Fosberg 6.
- Amaranthus viridis* L. Common along fences. K. P. Fosberg 3.
- Portulaca oleracea* L. Common. K. P. Fosberg 24.
- Pithecellobium dulce* (Roxb.) Benth. Rare, planted. K. P. Fosberg 22.
- Prosopis juliflora* (Sw.) DC. (sens. lat.). Rare, planted. K. P. Fosberg 25.
- Euphorbia geniculata* Ort. Abundant locally on small dune. K. P. Fosberg 8.
- Euphorbia hypericifolia* L. Common along fences and edges of walks. K. P. Fosberg 2.
- Ricinus communis* L. Common. K. P. Fosberg 10.
- Tribulus cistoides* L. Abundant. K. P. Fosberg 5.
- Thespesia populnea* (L.) Sol. Commonly planted. K. P. Fosberg 18.
- Terminalia catappa* L. Abundantly planted. K. P. Fosberg 23.
- Thevetia thevetioides* (H.B.K.) Schum. Planted, not common. K. P. Fosberg 19.
- Cordia sebestena* L. Planted, rare. K. P. Fosberg 21.
- Messerschmidia argentea* (L.) Johnst. Planted, occasional. K. P. Fosberg 14.
- Vitex trifolia* L. Planted, occasional. K. P. Fosberg 15.
- Scaevola frutescens* (Mill.) Kr. Rare, under *Messerschmidia* tree. K. P. Fosberg 13.
- Pluchea indica* Less. Uncommon, five or six plants seen. K. P. Fosberg 4.
- Pluchea odorata* (L.) Cass. Occasional. K. P. Fosberg 1.
- Sonchus oleraceus* L.? Occasional. K. P. Fosberg 12.

## Notes on Marine Algae of New Zealand. I.

VICTOR W. LINDAUER<sup>1</sup>

AS WOULD BE EXPECTED, considering its geographical position, New Zealand has always attracted the attention of the scientific collector, and it may, therefore, seem strange that certain conspicuous marine algae have hitherto escaped critical examination and, in some cases, have been overlooked entirely. This series of papers will deal with such, together with occasional notes on the New Zealand algal flora generally.

### Family PHAEOPHYCEAE

#### *Ectocarpus brachiolus* sp. nov.

Fig. 1*d-i*.

Frondibus minutis, 4 mm. altis, epiphyticis, orientibus e massa densa filorum serpentium; thallis tortuosis, eandem latitudinem semper servantibus, 15–24  $\mu$  latis, cacuminibus obtusis, articulis 1–4-plo latioribus, ramis raris, secundatis vel irregularibus, longis, saepius simplicibus, divaricatis, subapicaliter crescentibus, chromatophoris patinae similibus, nullis capillis; sporangia unilocularia non visa; sporangiis plurilocularibus (1) terminalibus, erectis, 51–62  $\mu$  longis, 34–45  $\mu$  latis, positis in pedicellis 0.5 mm. altis e cellulis 12 vel pluribus constantibus; (2) lateralibus, sessilibus vel cum pedicellis unicellularibus, 62–72  $\mu$  longis, 48  $\mu$  latis, saepius ad fila ad angulos rectos vergentibus.

Fronds minute, 4 mm. high, epiphytic, arising from a dense mass of creeping filaments; thalli tortuous, of same width throughout, 15–24  $\mu$  wide, tips obtuse, articulations 1–4 times width, branches sparse, secund or irregular, long, mostly simple, divaricating, growth subapical, chromatophores plate-like, hairs absent; unilocular

sporangia not seen; plurilocular sporangia (1) terminal, erect, ovoid-acuminate, 51–62  $\mu$  long and 34–45  $\mu$  wide, on pedicels 0.5 mm. high of 12 or more cells; (2) lateral, oval to ovoid, often bifurcate, sessile or with pedicels of 1 cell, 62–72  $\mu$  long and 48  $\mu$  wide, most often at right angles to the filament.

*E. brachiolus* has affinities with *E. rhodochortonoides* Boerg. but the dimensions of its cells and the shape and position of its plurilocular sporangia are different. On the other hand, the sporangia more closely resemble, but are not identical with, those of *E. breviararticulatus* J. Ag., being both shortly stalked and inserted at right angles, but the vegetative thallus shows important differences. In this connection it approaches more closely *E. variabilis* Vickers in which the cells are much shorter and of nearly the same length throughout.

*Distribution:* On *Cladophora colensoi*, in pools, covering part of the filament with a low, soft, yellowish, hairy fringe. Pegasus, Stewart Island, the type locality; in the early autumn.

Type specimen, No. 9975, Herbarium Lindauer.

#### *Sphacelaria stewartensis* sp. nov.

Fig. 1*a-c*.

Frondibus parvis, cristatis, epiphyticis, 4–5 mm. altis, orientibus e dense aggregatis intrudentibus filis, axibus primariis thallorum percurrentibus, 30–42  $\mu$  latis, cum paucis rhizoidibus descendentibus, axe mox subramo egerente pinnas longas, simplices vel sparse ramosas, 15–24  $\mu$  latas, axi primario similes, cacuminibus obtusis sed numquam conspicuis, interdum subattenuatis; articulis saepius longioribus quam latioribus, parte superiore parvis cuiusque cellularum maiore quam parte inferiore et pericys-

<sup>1</sup> Senior Research Fellow in the University of New Zealand at Auckland. Manuscript received March 29, 1949.



to distincto praedita, sectionibus longitudinalibus 1-3, sectionibus transversis saepe nullis, interdum singulis, numquam pluribus; capillis nullis; sporangiis unilocularibus 39-45  $\mu$  longis, 21-24  $\mu$  latis, numerosis, ovatis, saepius ternis vel quaternis in ramulis sympodialibus qui in seriebus irregularibus secundatis vel alternatis per maiorem partem thalli gignuntur; sporangia plurilocularia non visa; propagula non visa.

Fronds small, tufted, epiphytic, 4-5 mm. high, arising from closely packed penetrating filaments, main axes of thalli percurrent, 30-42  $\mu$  wide with but few descending rhizoids, axis soon giving off somewhat sparingly, long, simple or sparsely branched pinnae 15-24  $\mu$

wide similar to the main axis, tips obtuse but never conspicuous, sometimes somewhat attenuated; articulations usually longer than wide, the upper of each pair of cells larger than the lower and provided with a distinct pericyst, longitudinal divisions 1-3, transverse divisions usually wanting or one at the most; hairs lacking; unilocular sporangia 39-45  $\mu$  long, 21-24  $\mu$  wide, plentiful, oval, generally in threes or fours on sympodial branchlets which appear in irregular second or alternate series over most of the thallus; plurilocular sporangia not seen; propagula not seen.

The plant is epiphytic on the upper segments of *Xiphophora chondrophylla*, forming small, isolated tufts, which, when removed, leave small cavities in the surface of the host. The branches are long and straggly, the lowest generally longest.

This species is closest to *S. reinkei* Sauv., of Tasmania, which plant is epiphytic on *Cystophora*; but dimensions of the new species are smaller, its branching is pinnate and not appearing dichotomous; it has no hairs, no felted basal portion, and the number of transverse divisions of the articulations is fewer.

It also resembles *S. sympodicarpa* Sauv., of Europe, but is larger and has no creeping filaments; *S. chorizocarpa* Sauv., of Australia, but is lacking in hairs and plurilocular sporangia; *S. borneti* Reinke, but again has no plurilocular sporangia. Sauvageau, however, considers *S. borneti* to be identical with *S. reinkei* Sauv.

*Distribution:* Epiphytic on *Xiphophora chondrophylla* at Twilight Bay, Pegasus, Stewart Island, the type locality; most abundant in March.

Type specimen, No. 9955, Herbarium Lindauer; iso-types distributed in Lindauer (1948), *Algae Nova-Zelandicae Exsiccatae*, Fasc. XIII, No. 311.

#### *Spatoglossum chapmanii* sp. nov.

Fig. 2a-f.

Frond erecta, complanata, ecostata, subpalmata, dichotoma, haud concentrice striata, ad 80 cm. alta, membranosa vel cortacea, subglauca

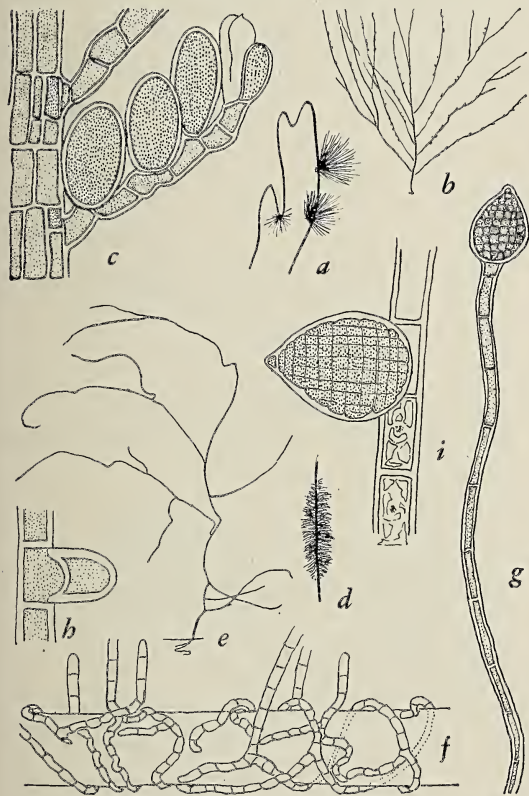


FIG. 1. Species of *Sphacelaria* and *Ectocarpus*. a-c, *Sphacelaria stewartensis* sp. nov.: a, in position on host ( $\times 1.5$ ); b, habit sketch ( $\times 5$ ); c, unilocular sporangium sympodium ( $\times 330$ ). d-i, *Ectocarpus brachiolus*: d, in position on host ( $\times 1$ ); e, habit sketch ( $\times 15$ ); f, creeping basal filaments on host; g, erect filament with plurilocular sporangium ( $\times 166$ ); h, initial of plurilocular sporangium ( $\times 330$ ); i, mature plurilocular sporangium (lateral) ( $\times 330$ ).

vel fusco-oleagina; haustorio stuposo; stipite brevi, stuposo, mox in laminam latam cuneatim patente, terminaliter diviso in numerosa longa vel subdichotomopalmata segmenta cuneos latos simulantia; sinubus rotundatis, rursus terminaliter divisus in lata linearia vel lingulata segmenta; apicibus rotundatis; marginibus intergris vel perraro dentatis; sporis in series plus minusve longitudinales sparsis.

Frond erect, flat, ecostate, subpalmate-dichotomous, not concentrically striate, up to 80 cm. high, membranous to coriaceous, greenish-olive to dark olive-brown, holdfast stupose, stipe short, stupose, soon expanding cuneately into a wide blade, splitting terminally into numerous long, palmate or subdichotomous-palmate broadly cuneate segments, sinuses rounded, dividing again into terminal broadly linear or lingulate segments, apices rounded, margins entire or very sparsely toothed; sporangia scattered or in more or less longitudinal bands.

Named in honour of Professor V. J. Chapman, of Auckland University College, New Zealand, whose assistance and friendship over a period of many years have been greatly valued.

The plants are probably dioecious, but the oögonia have not been definitely recognized. The antheridia are clustered into protruding, elongated, arched sori, up to  $210\ \mu$  wide and  $60\text{--}75\ \mu$  high, containing small, cuboidal loculi. The sporangia, each forming a quadrant of spores, are large, protruding, broadly pyriform or clavate, with very dark content and thick walls, solitary or closely scattered into somewhat longitudinal lines,  $84\text{--}108\ \mu$  high and  $75\text{--}105\ \mu$  wide, on stalks of 1–2 cells, the latter not always clearly visible. Structure of from 2–3 layers of large, colorless medullary cells, bounded by one row of smaller subcortical cells and one cortical layer of cuboidal photosynthetic cells in width equal to, or half that of, the subcortical cell immediately below.

There appear to be two very distinct ecological forms of this plant: the one greenish, membranous, broad, flabellate; the other brown, subcoriaceous, narrow, dichotomous. The former

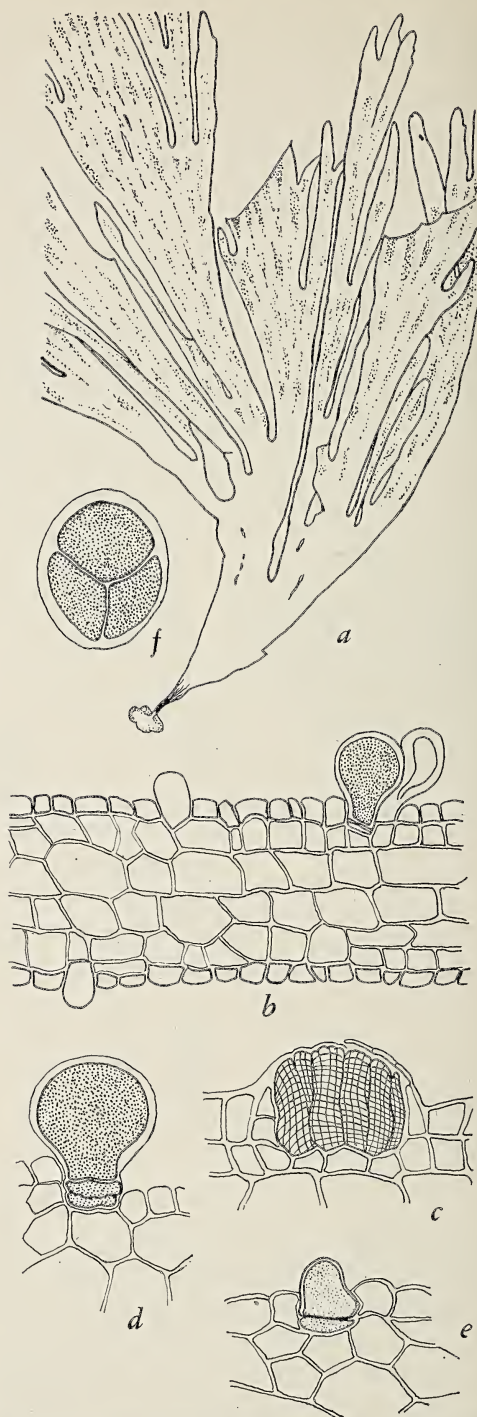


FIG. 2. *Spatoglossum chapmanii* sp. nov.: a, habit sketch ( $\times 0.2$ ); b, transverse section of frond; c, antheridial sorus in transverse section; d, tetrasporangium in transverse section; e, initial of tetrasporangium in transverse section; f, tetrasporangium, surface view.



grows in comparatively still, sheltered situations, and small plants of this form closely resemble *Taonia*, from which they differ macroscopically, in the lack of transverse, concentric bands. The latter is the commoner form.

In structure the plant agrees most closely with *S. solierii* (Chauv.) Kuetz., from the Mediterranean, as distributed by Schiffner, *Algae Marinae*, No. 689, but in vegetative habit is closer to *S. cornigerum* J. Ag. of Australia; but no exact comparison can be made until the Australian plant is more extensively collected.

**Distribution:** In the upper sub-littoral and extending downwards, often hanging from rock just below low-water line or growing on rocks on the bottom. Found more or less abundantly from Whangarei to the Bay of Plenty, Wellington, Bluff, Stewart Island (type locality). Spring and summer.

Type specimen No. 6702, Herbarium Lindauer; iso-types distributed in Lindauer (1946), *Algae Nova-Zelandicae Exsiccatae*, No. 209.

### *Myrionema compactum* sp. nov.

Fig. 3a-e.

Thallo epiphytico, pulvinum parvum tenuem glaucum lineamentis irregularibus formante, coniuncto ad nodos et internodos superiores *Hormosirae banksii* var. *gracilis*; strato basali prostrato monostromatico, constante e filis plus minusve tortuosis, dense adpressis, 9–12  $\mu$  diametro, subdichotome ramosis praesertim prope marginem; filis erectis 6–12 cellularum, brevibus, latis, cylindricis, obtusis, 54–100  $\mu$  altis, 15–21  $\mu$  latis, interdum duobus filis erectis ex eadem cellula basali orientibus; unilocularibus sporangiis sessilibus, rarius breviter pedicellatis, directe e strato librato orientibus aut rarius lateraliter e parte superiore filorum erectorum, late clavatis vel cylindricis, 40–80  $\mu$  altis, 15–27  $\mu$  latis, irregulariter per frondem sparsis; plurilocularibus sporangiis ad 12 ordines loculorum altis, in pedicellis 1–5 cellularum positos, seriebus e 2–4 constantibus, 60–99  $\mu$  altis, 15–

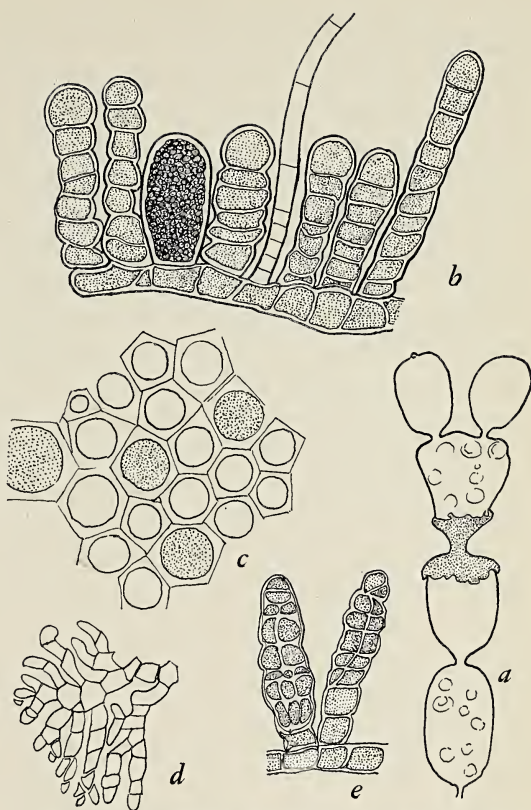


FIG. 3. *Myrionema compactum* sp. nov.: a, colony on host ( $\times 2$ ); b, erect filaments and unilocular sporangium ( $\times 325$ ); c, surface view showing erect filaments, sporangia (shaded), and a hair ( $\times 325$ ); d, tip of prostrate filament ( $\times 200$ ); e, plurilocular sporangia ( $\times 300$ ).

18  $\mu$  latis, parietibus transversis libratis; capillis 9  $\mu$  latis; chromatophoris parvis, disciformibus.

Thallus epiphytic, forming a small, thin, dull-grey, skin-like cushion irregular in outline, attached to the upper nodes and internodes of *Hormosira banksii* var. *gracilis*; prostrate basal layer monostromatic, composed of more or less tortuous, closely adpressed filaments 9–12  $\mu$  in diameter, subdichotomously branched, especially towards the periphery; erect filaments of 6–12 cells, short, broad, cylindrical, obtuse, 54–100  $\mu$  high and 15–21  $\mu$  broad, sometimes 2 erect filaments arising from the same basal cell; unilocular sporangia sessile, more rarely shortly pedicelled, arising directly from the horizontal stratum or, more rarely, laterally from the upper

part of the erect filaments, broadly clavate or cylindrical, 40–80  $\mu$  high and 15–27  $\mu$  wide, scattered irregularly over the frond; plurilocular sporangia up to 12 tiers of loculi in height, on pedicels of 1–5 cells, 2–4-seriate, 60–99  $\mu$  high and 15–18  $\mu$  wide, cross walls horizontal; hairs 9  $\mu$  wide; chomatophores small, disciform.

In its typical form the filaments are short and squat, but they vary a great deal in different areas of the colony, becoming longer and more slender. Unilocular and plurilocular sporangia are scattered promiscuously among the erect filaments or, in the case of the latter, taking their place in the course of the maturation of the filaments. As the colony matures the host seems to shed its cuticle to which the *Myrionema* remains attached, and the whole peels off naturally in due course. Dark-colored cells of homogeneous content are present, and resemble unilocular sporangia in size and shape and are, perhaps, merely degenerate sporangia.

The species under discussion is closest to *M. primarium* Setch. et Gard. (= *M. foecundum* f. *majus* S. et G.), from which it differs in its very much more massive proportions, especially as to width of erect filaments, hairs, and plurilocular sporangia, and in the number of loculi.

Growing on *Hormosira banksii* var. *gracilis* in tide-pools in the upper littoral.

*Distribution:* Known only from the type locality, Long Beach, Russell, Bay of Islands.

Type specimen, Lindauer, No. 11306 (formalin material), deposited in the Herbarium of Auckland University College.

#### Genus *Herponema* J. Ag.

On reading Agardh's (1882: 55) diagnosis of his new genus, *Herponema*, it becomes apparent that the characters emphasized by him are vague and have been the cause of much confusion in New Zealand, where two species of the genus supposedly existed. The following is a translation of the diagnosis:

*Herponema* J.Ag. mscr. — Frond flat-cushioned or subglobose, not particularly gelatinous, made up of a double layer: *axis* primarily de-

cumbent, and forming along the periphery of a centrifugally rising cushion rather simple or sparsely branched filaments radiating from the center and attached below, then forming a hypothallic layer at times barely distinguishable; *peripheral* layer consisting of rising filaments, then of filaments erect, very dense, cylindrical, articulate, thickish, stiff, all of similar shape; single sporangia terminal in the simple peripheral filaments, or lateral on the modified branchlets, hollow where the apex is broken.

Agardh included three species in *Herponema*: *H. pulvinatum*, *H. velutinum*, and *H. maculans*, which the writer proposes to discuss in turn.

#### *Herponema pulvinatum* J.Ag.

Agardh described the species from a specimen sent to him by Harvey under the herbarium name of *Ectocarpus pulvinatus*. The species was, however, never described by Harvey as such, but it is here suggested that Harvey described it at an earlier date (1855: 221) as *Sphacelaria pulvinata*, which name the plant still bears. It is unfortunate that Harvey's material is not available for comparison, but an analysis of the descriptions of *Herponema pulvinatum* and *Sphacelaria pulvinata* shows that the two plants are identical in all major details; furthermore, the habit and the host plant of both are the same. It is noteworthy that de-Toni (1895: 397 and 508) gives *Ectocarpus pulvinatus* Harv. as the synonym for both *Herponema pulvinata* and *Sphacelaria pulvinata*. Furthermore, the writer has collected a plant which answers to the description of *Sphacelaria pulvinata* Harv. and found it actually to be a species of *Sphacelaria*, and has distributed that plant in his *Algae Nova-Zelandicae Exsiccatae* (1942), No. 131.

#### *Herponema velutinum* (Grev.) J.Ag.

*H. velutinum* (Grev.) J.Ag. = *Sphacelaria* ? *velutina* Grev. = *Elachista velutina* (Grev.) Fries = *Ectocarpus velutinus* Kuetz. = *Streblonema* ? *velutinum* (Grev.) Thur., *vide* de-Toni (1895: 578).

This plant belongs to a group of parasitic species possessing vertical basal penetrating



filaments instead of a basal layer of horizontal filaments. Hamel (1931-39: XII), however, by implication designated it as the type species of *Herponema*. The writer, on the other hand, is of the opinion that although J. Agardh listed *H. pulvinata* and *H. velutina* before describing *H. maculans*, his description of the genus is essentially based on the latter species. The description fits it far better than it does either of the others, and the three diagrams (Tab. III, Figs. 4a, b, and c) are illustrations of that plant alone. It therefore seems more logical to regard *H. maculans* as type of the genus, especially since J. Agardh in his generic diagnosis points out that the plants possess two types of filaments, (1) horizontal and (2) erect; and since neither *H. pulvinata* nor *H. velutina* has a distinct basal system of horizontal filaments they cannot possibly be regarded as typical of the genus, or, in fact, as members of it. On the other hand most authors have placed the species *velutina* in *Ectocarpus*. In fact, the plant might well remain there until a more careful study has been made of the genera concerned, namely, *Ectocarpus*, *Herponema*, *Compsonema*, and *Hecatonema*.

#### *Herponema maculaeforme* (J. Ag.) Laing

Fig. 4a-j.

*H. maculaeforme* (J. Ag.) Lg. (orthog. mut.) = *H. maculans* J. Ag. = *Elachista maculaeformis* J. Ag. = *Herponema maculaeformis* (J. Ag.) Lg. (Note: J. Agardh had originally used the specific epithet *maculaeformis* but, by some oversight, he renamed the species *maculans* when transferring it to his new genus, *Herponema*. Laing (1929: 579) rectified the error but neglected to alter the gender of the termination, which has here been done.)

The identity of *Herponema maculaeforme* has for many years evaded New Zealand algologists. It had originally been described by J. Agardh (1877: 4) as *Elachista maculaeformis* but in 1882 (p. 56), he renamed it *Herponema maculans*. The plant does not, therefore, appear in Hooker's *Handbook* (1867), which was for

many years the only book of reference to the New Zealand algae possessed by local workers. In due course Kjellman (1891-93: 187) reduced the genus to *Ectocarpus*, as had also been

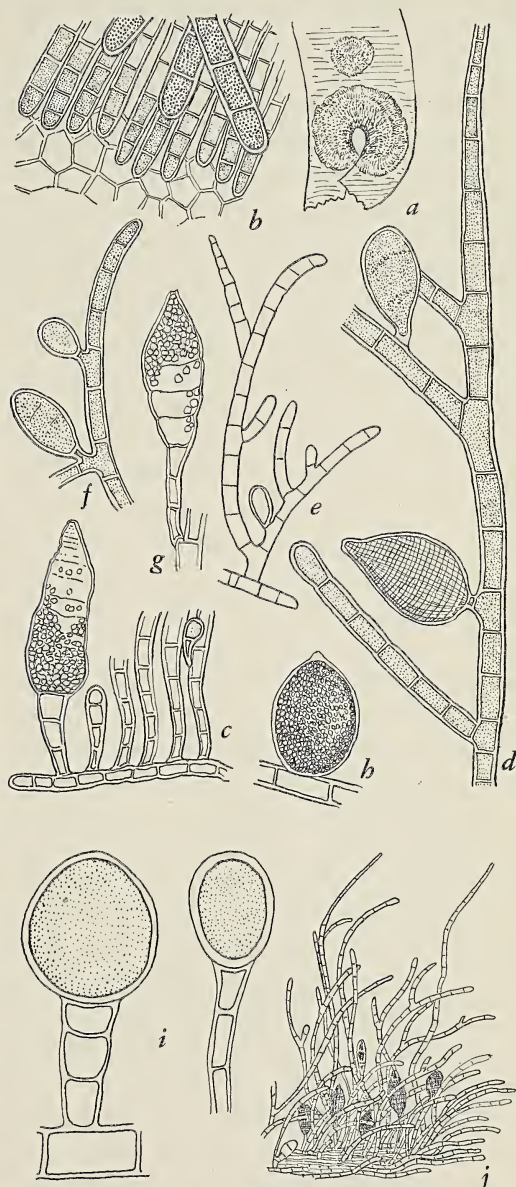


FIG. 4. *Herponema maculaeforme* (J. Ag.) Laing: a, colony on host ( $\times 2$ ); b, basal rhizoids with tips of three erect filaments for comparison ( $\times 150$ ); c, rhizoid with erect filaments ( $\times 150$ ); d, erect filament, somewhat straightened, with sporangia ( $\times 150$ ); e, small plant ( $\times 130$ ); f, tip of filament ( $\times 150$ ); g, h, old plurilocular sporangia ( $\times 150$ ); i, unilocular sporangia ( $\times 150$ ); j, showing basal, rising, and erect filaments, and sporangia ( $\times 20$ ).

done by Hauck (1885: 324-326); but much later Laing (1926: 138), and Lindauer (1947: 544-545), still included both *Herponema maculaeformis* and *H. pulvinata* in their lists.

As the description given by Agardh is rather vague and incomplete, a more detailed description is here given.

Thalli forming small, low, soft, furry, circular or confluent mats up to 1.5 cm. in diameter on the upper segments of *Xiphophora chondrophylla*, black when submerged, brown when dry, colonies consisting of a prostrate basal system of horizontal, closely adpressed, radiating filaments, 15  $\mu$  wide, and an erect system of slightly broader filaments, about 1 mm. high and 21-24  $\mu$  wide, tapering slightly downwards, arcuate, sparsely and irregularly divaricately branched, the branches most frequently arising on the convex side of the bent rachis and of the same width; tips obtuse, swollen or attenuated into a hair; articulations about 2-3 times as long as wide; protoplast of a dense golden-brown, granulated, with chromatophores closely packed, rod-like; unilocular sporangia globose or ovate, about 42-60  $\mu$  high and 45  $\mu$  wide, pedicellate on the prostrate filaments; plurilocular sporangia very numerous, irregular in size and shape, ovate, ovate-acuminate or siliquose, up to 150  $\mu$  high and 66  $\mu$  wide, pedicellate or sessile, terminal or lateral; loculi pluriseriate.

The height of the filaments varies a great deal according to their position in the colony. The plurilocular sporangia, recorded here for the first time, are excessively abundant and sometimes resemble the unilocular sporangia to such an extent that it is very difficult to distinguish between them; plurilocular sporangia of this type are, however, generally sessile and lateral on the branches, whereas the unilocular sporangia are usually pedicellate on the basal horizontal stratum.

*Distribution:* This plant is found from Wellington southwards, becoming very abundant on Stewart Island in April and May, otherwise appearing sporadically and sparsely throughout the year.

Distributed in Lindauer (1946), *Algae Nova-Zelandicae Exsiccatae*, No. 229, as *Hecatonema*?

It will be seen from the above description that the plant, *H. maculaeforme*, which alone remains of the triumvirate of J. Agardh's species, could seemingly be placed in Kuckuck's genus, *Compsonema* and, vague as Agardh's diagnosis of *Herponema* may be, it certainly appears to coincide with the description of what is understood as *Compsonema* in its broad sense, or with a group of algae which might embrace *Compsonema*. The generic epithet *Herponema* (1872) antedates *Compsonema* (1899); furthermore, Kuckuck's genus was built around a species which is still unique in the possession of but one chromatophore (*vide* Feldmann: 1937: 119) in each cell together with a conspicuously stratified filament producing endogenous hairs. Should *Compsonema* be accepted in this narrow sense it is plain that at least some of the Setchell and Gardner species attributed to *Compsonema* do not belong there, but should, perhaps, be included in the older genus, *Herponema*, and it is possible that some species of *Hecatonema* would be more properly attributed to *Herponema*, or that the former genus might be entirely absorbed by the latter.

#### *Hapalospongidion durvilleae* sp. nov.

Fig. 5e-i.

Thallis parasitica, erectis, pannos humiles ellipticos in *Durvillea antarctica* formantibus, filamentis artis, paene ecoloribus, 525-600  $\mu$  altis, 11.25  $\mu$  latis, filamentis singulis constantibus e cellulis ad 15, cellulis 3-6-cies longioribus quam latioribus; sporangiis unilocularibus ellipsoidis, 71  $\mu$  altis, 22.5  $\mu$  latis, terminalibus in brevibus erectis filamentis.

Thalli parasitic, erect, forming low, ellipsoidal patches on *Durvillea antarctica*; filaments simple, narrow, almost colorless, 525-600  $\mu$  high and 11.25  $\mu$  wide, each filament consisting of up to 15 cells, cells 3-6 times as long as wide; unilocular sporangia ellipsoidal, 71  $\mu$  long and 22.5  $\mu$  wide, terminal on short erect filaments. The nature of the basal system of penetrating



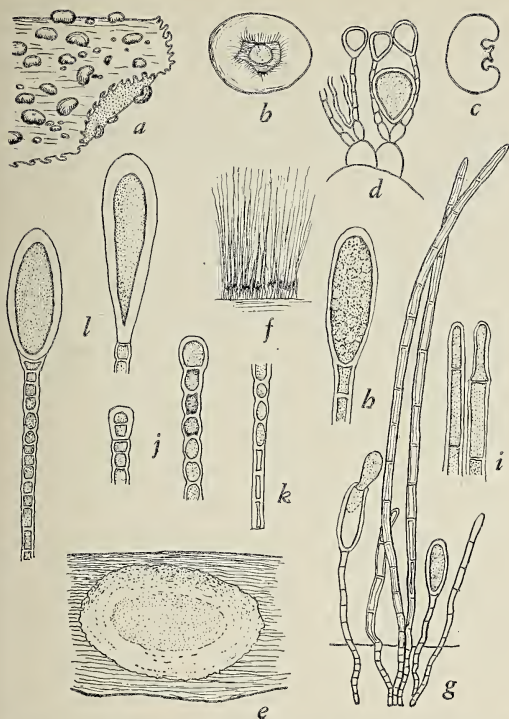


FIG. 5. Species of *Leathesia* and *Hapalospongidion*. a-d, *Leathesia novae-zelandiae* sp. nov.: a, colonies on host ( $\times 0.5$ ); b, undersurface ( $\times 2$ ); c, vertical cut through long axis of smaller specimen ( $\times 2$ ); d, paraphyses and sporangia (one dehiscent) ( $\times 140$ ). e-i, *Hapalospongidion durvilleae* sp. nov.: e, on host ( $\times 0.5$ ); f, habit sketch ( $\times 35$ ); g, filament with penetrating rhizoids and sporangia (one injured) ( $\times 150$ ); h, a sporangium ( $\times 280$ ); i, tips of filaments ( $\times 266$ ). j-l, *Hapalospongidion saxigenum* sp. nov.: j, tips of filaments ( $\times 166$ ); k, base of filament ( $\times 166$ ); l, unilocular sporangia ( $\times 170$ ).

filaments has not yet been satisfactorily determined.

The plants form small, oval patches at first, but later these become confluent and cover large areas within the margins of the blade of the host, not only on one surface of the blade but also on the opposite surface, the colony assuming exactly the same size and shape of that on the opposing surface, as if the parasite had grown right through the thallus of its host. The color, *en masse*, is dark brown and velvety but, on drying, it becomes yellowish-sienna and is very conspicuous on the dark, almost black frond of the dry *Durvillea*. The protoplast is very

light straw-colored, almost colorless under the microscope, but the sporangia are somewhat darker and very numerous in a low line among the long, erect filaments. This lack of color of the protoplast is in accordance with the plant's parasitic state. The chromatophores are small, disc-shaped, sparse, except at the tips.

This species may prove to belong to a new genus but in the meantime, until the plant is cultured, it is as well to place it here tentatively.

*Distribution*: So far known only from Stewart Island, the type locality, where it is abundant in autumn and winter.

Type specimen No. 6253, Herbarium Lindauer; iso-types were distributed in Lindauer (1946), *Algae Nova-Zelandicae Exsiccatae*, No. 230, as *Herponema*?

#### *Hapalospongidion saxigenum* sp. nov.

Fig. 5j-l.

Thallis minutis, erectis, aggregatis, fulvis, lubricis; filis simplicibus, arcte clavatis, 225–725  $\mu$  altis, 6–18  $\mu$  latis, constantibus e cellulis ad 60, cacuminibus obtusis, cellulis vix longioribus quam latoribus, paene tumido-cylindricis vel moniliformibus, cellulis basalibus aliquanto arctioribus, orthogoniis, ecoloribus, 2-plo longioribus quam latoribus; chromatophoris minutis, disciformibus; unilocularibus sporangiis grandibus, terminalibus, ovatis vel clavatis, 105–170  $\mu$  altis, 36–45  $\mu$  latis, parietibus cellularum conspicue crassis, pedicello constante e 12 vel pluribus cellulis, superne 12  $\mu$  latis, infra 4–6  $\mu$  latis; sporangia plurilocularia non cognita.

Thalli minute, erect, gregarious, dull yellowish-brown, lubricous; filaments simple, narrowly clavate, 225–725  $\mu$  high and 6–18  $\mu$  wide, consisting of up to 60 cells, tips obtuse, cells scarcely longer than wide, somewhat barrel-shaped or moniliform, basal cells somewhat narrower, rectangular, colorless, twice as long as wide; chromatophores minute, disciform; unilocular sporangia large, terminal, oval or clavate, 105–170  $\mu$  high and 36–45  $\mu$  wide, with conspicuously thick cell walls, pedicel of 12 or more cells 12  $\mu$  wide above and 4–6  $\mu$  wide below;

plurilocular sporangia unknown. The basal distromatic or tristromatic layer characteristic of the genus is barely distinguishable in this species, but it appears to exist.

The new species is closely related to *H. gelatinosum* Saunders in habit and stature but differs principally in the absence of plurilocular bodies, and in the poorly developed basal layer. It also has affinities with *H. pangoensis* (Setch.) Hollenbg. which is, however, smaller in its dimensions.

Forming low, slippery, continuous, suede-like patches mostly of large size on smooth boulders, somewhat resembling *Ralfsia*, but not crusty. On removal from rocks it becomes a pulpy, gelatinous mass. Small fragments on the microscope slide press out, under the cover slip, into circular tufts of radiating filaments with the bases closely adpressed in the center.

*Distribution:* In the intertidal region in the more exposed situations probably throughout New Zealand. Definitely known from Russell, Pihama (Taranaki), Kaikoura, Stewart Island (the type locality). Mostly summer and autumn.

Type specimen No. 11320, Herbarium Lindauer, deposited in the Herbarium of Auckland University College.

#### *Leathesia novae-zelandiae* sp. nov.

Fig. 5a-d.

Frondibus epiphyticis, fusco-oleaginis, glabris, solidis, hemisphaericis, ad 7 mm. diametro, 4 mm. altis, filamenta e 5-9 cellulis assimulantibus, clavatis, cellula terminali obovoida; sporangiis unilocularibus obovoidis, 71-90  $\mu$  longis, 34-45  $\mu$  latis.

Fronds epiphytic, olive-brown, glabrous, solid, hemispherical, up to 7 mm. in diameter and 4 mm. high, assimilating filaments of 5-9 cells, clavate, the terminal cell obovoid; unilocular sporangia obovoid, 71-90  $\mu$  long and 34-45  $\mu$  wide.

The juvenile frond arises from a prostrate basal system of radial, compact, branched filaments, and may readily be mistaken for *Myriophyllum*. The periphery of the mature thallus is

oval, circular, or slightly irregular in outline, convolutions on the surface are wanting, but a dimple sometimes develops in the center of the rounded upper surface. The under surface is concave even in specimens of 1 mm. in diameter and less, so that the detached thallus resembles the "cap" of a mushroom. The attachment appears in the center of the concavity as a slightly raised dark brown patch, 1.5-2 mm. in diameter in the largest specimens; this may be distinctly seen from the reverse side of the frond of the host plant if held to the light.

This plant is distinct from any other species of the genus known to the author.

*Distribution:* Epiphytic on both surfaces of the fronds of *Gigartina lanceata* and, possibly, on other foliose species of the genus, occupying the spaces between the superficial lingulae, if present. Sublittoral along the shores of Stewart Island, the type locality. Common at midsummer.

Type specimen No. 8132, Herbarium Lindauer; iso-types distributed in Lindauer (1947), *Algae Nova-Zelandicae Exsiccatae*, Fasc. XI, No. 256.

#### *Durvillea willana* sp. nov.

Fig. 6

Frondibus 5 m. vel ultra longis, fuscis, coriaceis; disco scutato; stipite crasso, cylindrico, 1 m. longo, planius et latius crescente in latam complanatam laminam in segmenta loris similia plus minusve alte divisam; stipite ferente multas proliferationes irregulariter positas in omnibus longitudinis partibus, proliferationibus singulis efformatis e stipite, lamina, segmentis axem principarium simulantibus, interdum in margine positus in superiore complanata parte stipitis primarii.

Frond 5 m. or more long, dark brown, leathery, attachment a thick, scutate disc, stipe stout, cylindrical, 1 m. or more long, flattening and widening upwards into a broad complanate blade split more or less deeply into strap-like segments; stipe bearing many proliferations placed irregularly on all sides throughout its length, each consisting of a stalk, blade, and



segments similar to the main axis, proliferations sometimes becoming marginal on the upper, flattened portion of the stipe.

The plant somewhat resembles *Sarcophycus potatorum*, differing from it mainly in the presence of secondary branches, produced often in



FIG. 6. *Durvillea willana* sp. nov.: habit sketch ( $\times 0.08$ ).

large numbers, sometimes 40 or more, from the main stipe. It differs from *Durvillea antarctica*, not only in its proliferated stipe, but in the absence of an internal layer of large, empty, colorless, columnar, polygonal chambers, which make the blade cushion-like to the feel, agreeing in that respect with *D. harveyi* of the Cape Horn region and *Sarcophycus potatorum* of Tasmania and Australia.

At low water, instead of sprawling on or hanging from the rocks, as is the habit of *D. antarctica*, the stipe of the new species stands erect with the blade drooping from its extremity. Hence the two species may readily be distinguished at a distance.

*Distribution:* Generally fringing rocks over a clean, sandy bottom in comparatively shallow water; missing where clean sand is absent; often growing with *D. antarctica* in suitable situations, but generally on the seaward side of it on a gently shelving bottom, and never with it over deep water. Common at Taylor's Mistake (Christchurch), Timaru, and south to Stewart Island; N. W. Nelson Province.

Named in honor of Mrs. Eileen Willa of Half Moon Bay, Stewart Island, whose tireless enthusiasm and intensive collecting have greatly assisted the author in his work.

*Carpophyllum plumosum* var. *quercifolium*  
var. nov.

Fig. 7*d-e*.

Frondibus erectis, ad 90 cm. altis, distichis; rachidibus complanatis, sinuosis, ramulis marginaliter et sat distanter etrudentibus, habitum speciei retinentibus; laminis basalibus querciformis, 5 cm. longis, cacuminibus obtusis, lobis obtusis; laminis medialibus arctioribus, lobis ornatis, acutis; laminis terminalibus simplicibus, parvis, infra attenuatis; vesiculis parvis, ellipsoideis, pedicellularibus; receptaculis paniculatis.

Frond erect, up to 90 cm. high, distichous, complanate, sinuous, the branches emerging marginally and somewhat distantly, in general habit resembling the original species; basal "leaves" oak-shaped, 5 cm. long with obtuse tips and blunt lobes; medial narrower, lobed, acute; terminal simple, small, attenuate below; vesicles small, ellipsoidal, pedicelled; receptacles panicled.

*Distribution:* In the sublittoral fringe at Chatham Islands, the type locality.

Type specimen No. 2480, Herbarium Lindauer.

## Family RHODOPHYCEAE

*Gigartina pachymenioides* sp. nov.

Fig. 7a-c.

Frondibus erectis, fusco-rubris, complanatis, sub-cartilaginosis, ad 20 cm. altis; basi incrustata; stipite 1 cm. long, terete, paulatim patente in magis minusve certam "apophysim" ad 3 cm. longam, 1 cm. latam; lamina simplici, linearilanceolata vel flabellata, plurimis furcis diversis; basi laminae cuneata vel obtuso-rotundata ad 6 cm. lata; apicibus attenuatis; margine sinuoso, crenulato, subtiliter undulato vel minutis obtusis processibus ornato; superficie frondis tetrasporicae levi, e cystocarpio constante, sparse vel dense operta brevibus lingulis vel proliferationibus volutis simplicibus aut ramosis linearibus; cystocarpiis globosis, positis in marginalibus vel superficialibus papillis, ostiolatis, tetrasporangiis in soris in serie subcorticali sparsis, cruciatis.

Fronds erect, dark red, complanate, sub-car-

tilaginous up to 20 cm. high, base incrusting, stipe 1 cm. long, terete, widening gradually into a more or less distinct "apophysis" up to 3 cm. long and 1 cm. wide, blade simple, linear-lanceolate or flabellate and several times divergently forked, base of blade cuneate or broadly rounded up to 6 cm. wide, apices attenuated, margins sinuous, crenulate, finely undulate or provided with minute, blunt outgrowths; surface of tetrasporic frond smooth, of the cystocarpic covered sparsely to densely with short lingulae or coiled simple or branched linear proliferations; cystocarps globose, borne on marginal or superficial papillae, ostiolate; tetrasporangia in scattered sori in the sub-cortical layer, cruciate.

The form of the plant is very varied, the width and shape of the segments in particular being very irregular. There are no outgrowths from stipe or "apophysis," nor are papillae or reproductive organs present on apophysis or basal part of blade. The frond has a strong tendency to curl, so that the margins are wavy and the tips often spirally twisted. Unlike normal foliose *Gigartina*, it does not decompose quickly when exposed to rain in wrack along the shore, but remains firm and solid for a much longer period, in the manner of *Pachymenia*; hence its specific name.

No suggestions can be offered at the moment as to the probable affinities of this species in this most difficult genus. *G. pachymenioides*, beyond belonging to the foliose group of *Gigartina*, has very little in common with other local species.

*Distribution:* At and above low-water mark on cliff faces and rocks on Stewart Island, the type locality.

Type specimen No. 7403, Herbarium Lindauer; iso-types distributed in Lindauer (1948), *Algae Nova-Zelandicae Exsiccatae*, Fasc. XIII, No. 321.

*Callithamnion levringii* sp. nov.

Fig. 8a-d.

Frondes perdelicata, rosea, disticha, decompos-

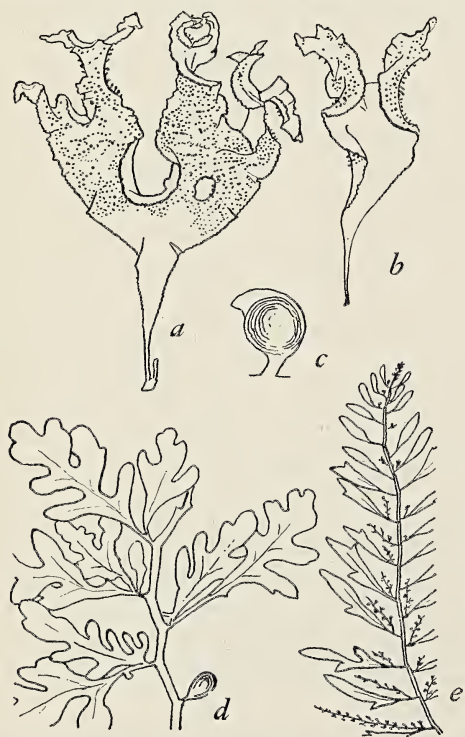


FIG. 7. Species of *Gigartina* and *Carpophyllum*. a-c, *Gigartina pachymenioides* sp. nov.: a, b, habit sketches ( $\times 0.6$ ); c, cystocarp ( $\times 5$ ). d, e, *Carpophyllum plumosum* var. *quercifolium* var. nov.: d, habit ( $\times 0.6$ ); e, fertile tip ( $\times 0.6$ ).



ita, filamentosa, monosiphonia, ecorticata, ad 10 cm. alta, oriente e rhizoidibus basalibus; axe primario percurrente, flexuoso, in vicem sparse ramoso, ramis inferis longioribus, patentibus, laxis, ramulis alternis singulos ad articula singula ornatis, brevibus, fastigiatis, alterno-dichotomis; ramulis ultimis saepe secundis; articulis axis primarii 2 mm. longis, 0.3 mm. latis, ramulorum 6-cies longioribus quam latioribus, cacumini-bus obtusis; cystocarpiis non observatis; sporangiis (?) obovoidis, breviter pedicellatis intra furculas ramulorum.

Frond very delicate, rose-red, distichous, decom-pound, filamentous, monosiphonous, ecorticate, up to 10 cm. high, arising from basal rhizoids; main axis percurrent, flexuous, sparsely alternately branched, branches longest below, patent, lax, clothed with alternate branchlets, one to each articulation, short, fastigiate, alternate-dichotomous, the ultimate ramuli often secund; articulations of main axis 2 mm. long, 0.3 mm. wide, of the ramuli 6 times as long as wide, tips obtuse; cystocarps not seen; sporangia (?) obovoid, shortly pedicellate within the forks of the ramuli.

The genus to which this plant belongs is questionable and may require revision when sexual plants are discovered. The form of the sporangium (?) is most unusual. It is first recognizable as such as the swollen and enlarged terminal cell of a lateral or axial 2-celled branch, the lower cell acting as a pedicel. At this stage it resembles a monosporangium. As it enlarges, the content is divided at the lower third, the upper larger part appearing to have been cut off from the lower part and resting in it. It now appears as an unequal bisporangium. Maturation progresses most rapidly at the distal end and soon the content is divided at the upper third. The sporangium (?) is now vaguely seiospore-like, but no further development has been observed.

In general vegetative habit the plant resembles *C. licomophorum* Harv., of Victoria, Australia, and is, perhaps, nearest to it, although

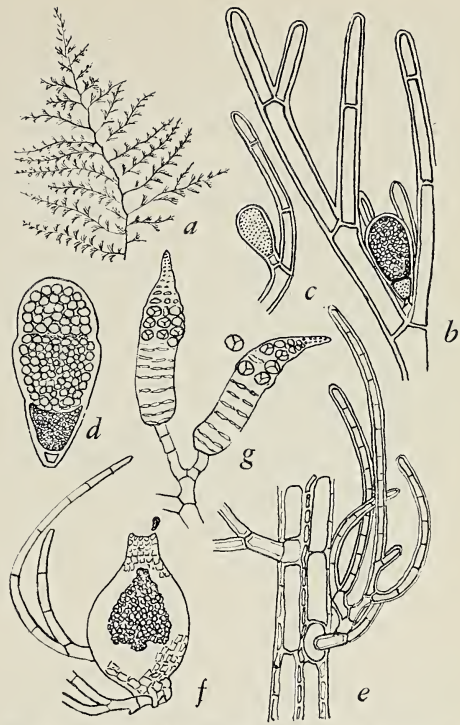


FIG. 8. Species of *Callithamnion* and *Dasya*. a-d, *Callithamnion levringii* sp. nov.: a, pinna ( $\times 0.6$ ); b, tip bearing polysporangium ( $\times 65$ ); c, young polysporangium ( $\times 65$ ); d, polysporangium almost mature ( $\times 120$ ). e-g, *Dasya subtilis* sp. nov.: e, portion of frond ( $\times 120$ ); f, cystocarp ( $\times 120$ ); g, tetra sporangial stichidia ( $\times 120$ ).

the New Zealand specimens lack rhizoids coating the main divisions and the reproductive bodies are dissimilar.

*Distribution:* So far found only in the drift at Pihama, Taranaki, the type locality. Summer.

Type specimen No. 7165, Herbarium Lindauer; iso-types distributed in Lindauer (1948), *Algae Nova-Zelandicae Exsiccatae*, Fasc. XIII, No. 325.

#### *Dasya subtilis* sp. nov.

Fig. 8e-g.

Frondibus parvis, rubescentibus, cristatis, teneris, flaccis, filiformis, 2-4 cm. altis, decompositis, in vicem subdistichose ramosis; ramis primariis corticatis, pericentricis cellulis 5; ramulis ultimis monosiphonis, dichotomis, divaricatis; articulis 3-4-cies longioribus quam latioribus, cacumini-bus obtusis; ramulis terminalibus saepe aggregatis et involutis; cystocarpiis magnis, sessi-

libus in polysiphoniis basalibus segmentis lateralium, late ovoidis, ore conspicuo ornatis; tetrasporangiis positis in 2-3 regularibus seriebus in magnis fusiformis stichidiis in monosiphoniis pedicellis.

Fronds small, pink, tufted, tender and flaccid, filiform, 2-4 cm. high, decompound, alternately subdistichously branched, main branches corticate, pericentral cells 5, ultimate branchlets monosiphonous, dichotomous, divaricate, tips obtuse, articulations 3-4 times as long as wide, terminal ramuli often crowded together and incurled; cystocarps large, sessile on the polysiphonous basal segments of laterals, broadly ovoid with a prominent orifice; tetrasporangia in 2-3 regular rows in large, fusiform stichidia on monosiphonous pedicels. Summer; annual.

The plant is closely allied to *D. collabens* H. et H. but is very diminutive in size and is epiphytic upon a different type of host, as well as being restricted in range to the north of New Zealand. It is also able to withstand exposure to the atmosphere during low tides.

*Distribution:* On *Corallina* in the littoral region at low-water neap tide during the summer months; common at Long Beach, Russell (type locality); Auckland.

Type specimen No. 947, Herbarium Lindauer; iso-types distributed in Lindauer (1947), *Algae Nova-Zelandicae Exsiccatae*, Fasc. XII, No. 300, as *Heterosiphonia subtilis*.

#### ACKNOWLEDGMENTS

The writer is indebted to Professor V. J. Chapman of Auckland University College for many invaluable suggestions and continual help during the necessary research; to Professor G. F. Papenfuss of the University of California for much assistance in determining specimens and for consenting to read and criticize the original manuscript; to Mr. L. W. Crawley of Auckland University College for translating the descriptions into Latin; and to the Research Fund

Committee of the University of New Zealand for the liberal grant made in connection with the writer's researches.

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## NOTES

### Notes on Three Beaked Whales from the Aleutian Islands

On June 6, 1947, in the company of a shore party from the motorship "Black Douglas," I discovered the putrid carcass of a male *Ziphius cavirostris* on the northeast side of Samalga Island, Aleutian Islands, Alaska. From this carcass, which was about 19 feet long, I recovered a portion of the right mandible, the symphyseal region of both mandibles, and a portion of the mesorostral ossification. Dr. Remington Kellogg has kindly identified the remains and has placed them in the U. S. National Museum as Specimen No. 276,022 (original No. VBS 1371).

On November 12, 1947, I visited Amchitka Island, in the western Aleutians, and was told by Elmer C. Hanson that the body of a small whale had appeared on the beach near Constantine Harbor some months before. The waves pounded the body to pieces, but Mr. Hanson saved one tooth. In a letter of March 18, 1948, Dr. Remington Kellogg writes that "the large flattened tooth which is broken off above the base belonged to some species of *Mesoplodon*. It is not sufficiently complete for precise identification."

To the best of my knowledge, not over ten skulls or fragmentary specimens of *Berardius bairdii* Stejneger have been preserved. These have been collected around the rim of the north Pacific from Santa Cruz, California, and Tokyo Bay, Japan, on the south to the Pribilof and Commander Islands on the north. Through the kindness of Henry Swanson, I am able to add a recent specimen, the skull of a subadult of unknown sex, which is now in the U. S. National Museum, Biological Surveys Collection, Specimen No. 33431X (original No. BDM 294).

In the fall of 1948 Aleut natives saw the carcass of this specimen stranded on the beach about 5 miles from the village of Unalaska. I tried to recover it in November but could not land on account of a heavy surf. Mr. Swanson subsequently chopped off the head and sent it to Seattle, where it arrived on December 18, 1948.

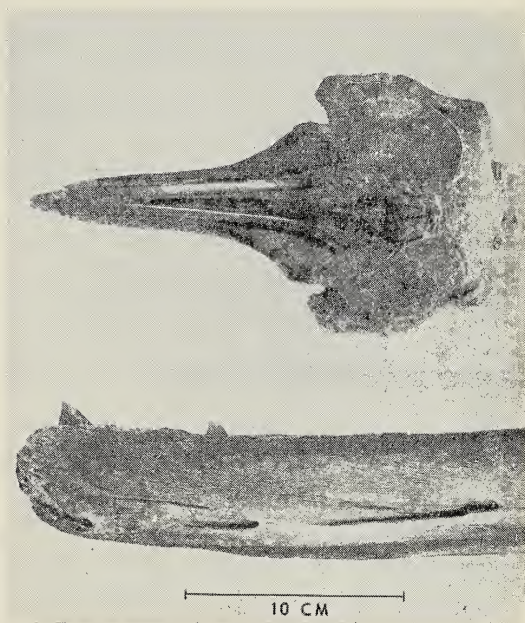


FIG. 1. Skull of Baird beaked whale from Unalaska, Alaska. Above, dorsal view; below, left mandible, anterior portion, outer face, showing the two teeth. (Scale applies to lower figure only.) (Photographs No. 2493 and 2495.)

Sea gulls, ravens, and foxes had torn at the flesh over a period of several months, with the result that the original contour of the head was lost. Karl W. Kenyon and I cleaned the skull in boiling dilute sodium hydroxide, and found that it measured 1,043 mm. in greatest length, and 537 mm. in greatest breadth (Fig. 1).

*Berardius bairdii* normally has four teeth, two in each half of the lower jaw. In my specimen the larger, foremost tooth of the pair is firmly rooted while the smaller, hindmost one can be easily picked out with the fingers.—Victor B. Scheffer, U. S. Fish and Wildlife Service, Seattle, Washington.

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Box 1580  
Wellington, New Zealand



## News Notes

*Seashore Treasures*.—Dr. Charles H. Edmondson, Zoologist at the Bernice P. Bishop Museum, and Professor Emeritus of Zoology at the University of Hawaii, has combined his life-long interest in the reef and shore fauna of Pacific islands with the zeal of a scientist who has made of his work a hobby, and has written this book, and illustrated it, "for the younger scientists whose interest in things of the natural world, including seashore life, is beginning to develop." The several chapters, on reef fish and corals, on shells and slugs and squids, on crabs and sponges, and on many of those other forms of animal life found along so many Pacific shores, are written principally for the younger reader, but they will serve well to educate even the older reader in the facts of seashore life that may be new to him and to give him the answers to those many questions which even the youngest of visitors to the seashore, not yet old enough to read but already old enough to ask too many questions, will put

to their elders when the family goes to the beach.

EDMONDSON, CHARLES H. *Seashore Treasures*. 144 pp., 200 figs. and photographs. Pacific Books, Palo Alto, California. Price \$3.50.

The *Proceedings* of the South Pacific Commission's Third Session, held at Noumea, New Caledonia, from May 7 to 17, 1949, contains information of significance to scientists interested in certain of the economic and public health projects being directed by the Commission. Some of the research projects being contemplated or investigated are concerned with tuberculosis, filariasis, and other infectious diseases; nutritional and dietary problems; infant and maternal welfare; introduction of economic plants; tropical pasture improvement; hydrological and forest reserves; erosion control; fisheries research; and biological control of weeds and insect pests.

*Proceedings. South Pacific Commission*, Third Session. 3/Sec. 39/Rev. 1 and Pr. 8. 22 pp., with 3 appendices; mimeographed. Noumea, New Caledonia, 1949.

ERRATA IN VOLUME III, NO. 3 (JULY)

Page 241, Key III, line 3. *For appically, read apically.*

Page 249, legend for Fig. 5, line 3. *For Cowan, read (Wawra) Hbd.*

Page 270, line 1. *For LANJOW, read LANJOUW.*



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———. 1920b. Cerotrioza (Psyllidae, Homoptera). *Hawaii. Ent. Soc., Proc.* 4 (2): 374-375.

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# PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



IN THIS ISSUE: de Laubenfels—*Sponges of Kaneohe Bay* • Storey—*Chromosome Numbers of Passiflora* • Kawaguti—*Corculum and Zooxanthellae* • Palmer—*Mean Temperatures at Honolulu* • Fisher—*Birds of Yap* • Chapman—*Algal Communities, Stanmore Bay, N. Z.* • NOTES



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MAR 17 1950





# The Sponges of Kaneohe Bay, Oahu<sup>1</sup>

M. W. DE LAUBENFELS<sup>2</sup>

THE HAWAIIAN ISLANDS lie near the center of the north tropical Pacific Ocean. The island of Oahu is in the midst of these islands Kaneohe Bay is near the middle of the windward side of Oahu, which side extends from northwest to southeast. The whole bay extends slightly over 11 kilometers along the coast, but is only some 3 kilometers (2 miles) deep. It is sheltered by extensive off-shore coral reefs, however, so that the water in it is much calmer than that of the open ocean. The southeast end of the bay is further sheltered by Mokapu peninsula so that it is here three-fourths landlocked; a roughly circular area some 3 kilometers in diameter is thus especially sheltered. The present study is based upon collections within this latter area which includes the junction of latitude  $21^{\circ} 26' \text{ N.}$  and longitude  $157^{\circ} 48' \text{ W.}$

The deeper portions of Kaneohe Bay have a sand bottom; practically no sponges occur on sand. There are many patches of coral scattered throughout the bay, coming up to extreme low tide level, thus nearly but not quite 1 meter below the high tide surface. Such masses are often more than 100 meters in diameter, and have a vertical measurement above the floor of the bay of 10 to 15 meters. Much of the outer or fringing area of each is living coral, but the bulk of each mass is dead coral. There are innumerable interstices, and these are teeming with inverte-

brate life, including sponges. To collect and study this fauna, large armful-sized masses of coral were broken off, hauled to the surface, and placed on a boat where they were broken into small bits by means of hammers and crowbars. It is common to find that 5 to 10 per cent of the surface of the dead coral, down in these narrow crevices, is covered with living sponges. These are, however, always thin, often as thin as paper. Such incrustations are difficult to detach, or to study in any other way.

Much of the study of Kaneohe Bay was conducted at or near the island that has long been known by the Hawaiian name of Moku O Loe, but which has lately been termed Coconut Island. It is less than a kilometer in greatest dimension. Several man-made lagoons about 20 to 80 meters in length and connected to each other, and to the ocean, by channels that are 2 to 8 meters wide, have been constructed. In the channels sponges grow luxuriantly, and an individual sponge colony may quadruple its mass in 1 year's growth. In the calmer waters of the lagoons a few scattered sponges occur, some of rather large size (10 to 20 cm. high), but it is evident that there they grow very slowly; individual colonies showed so little growth in a year's time that it could not be measured. Doubtless there was some growth, but probably less than 10 per cent increase. These larger lagoon specimens are probably several years old, perhaps even 10 years old. Larger sponges in the channels may be only 10 months old.

Field investigation was carried out approximately once a month from September, 1947, to May, 1948 (9 months), and again in

<sup>1</sup>Research Paper No. 9, Cooperative Fisheries Research Staff, Territorial Board of Agriculture and Forestry and University of Hawaii; Contribution No. 1, Hawaii Marine Laboratory.

<sup>2</sup>Department of Zoology and Entomology, University of Hawaii. Manuscript received April 2, 1949.



FIG. 1. Map of the island of Oahu showing Kaneohe Bay and Moku O Loe.

October, 1948. About a dozen species of sponge were found to be fairly common or regular in occurrence in accessible locations, and a second dozen were found, but were rather rare and uncommon. It is certain that continued search would gradually but steadily build up this latter category to a total of at least 2 or 3 dozen. The same amount of effort and time expended on the Pacific coast of the United States, for areas of similar size and placement, would yield just about the same number and average size of specimens. The same may also be said for the coasts of England in particular and northwest Europe in general. In contrast, the Atlantic coast of the United States yields only half as many species, but typical regions in the Mediterranean and in the West Indies yield half again as many species, and the individual colonies are many times larger.

The possible faunal relationships of Ha-

waiian species to those of other parts of the world are interesting. Of the 23 species here discussed, 12 (or more than half) are new species. Of the 12, 7 (or more than half) are new genera. This is not unexpected in view of the insular location. Of the species that are here identified with previously named forms, four are circumtropical—almost to be called cosmopolitan—two are East Indian, two are from the Pacific coast of Panama, the others are from scattered localities. The two Panamanian forms conceivably may have been brought to Hawaii on ship bottoms; at least one of them is abundant on those that are dry-docked at Pearl Harbor. Conversely, they may have been taken to Panama from Hawaii.

The study of sponges in the field is complicated nearly everywhere by the occurrence of certain species of ascidians of the family Diademnidae which closely resemble encrust-



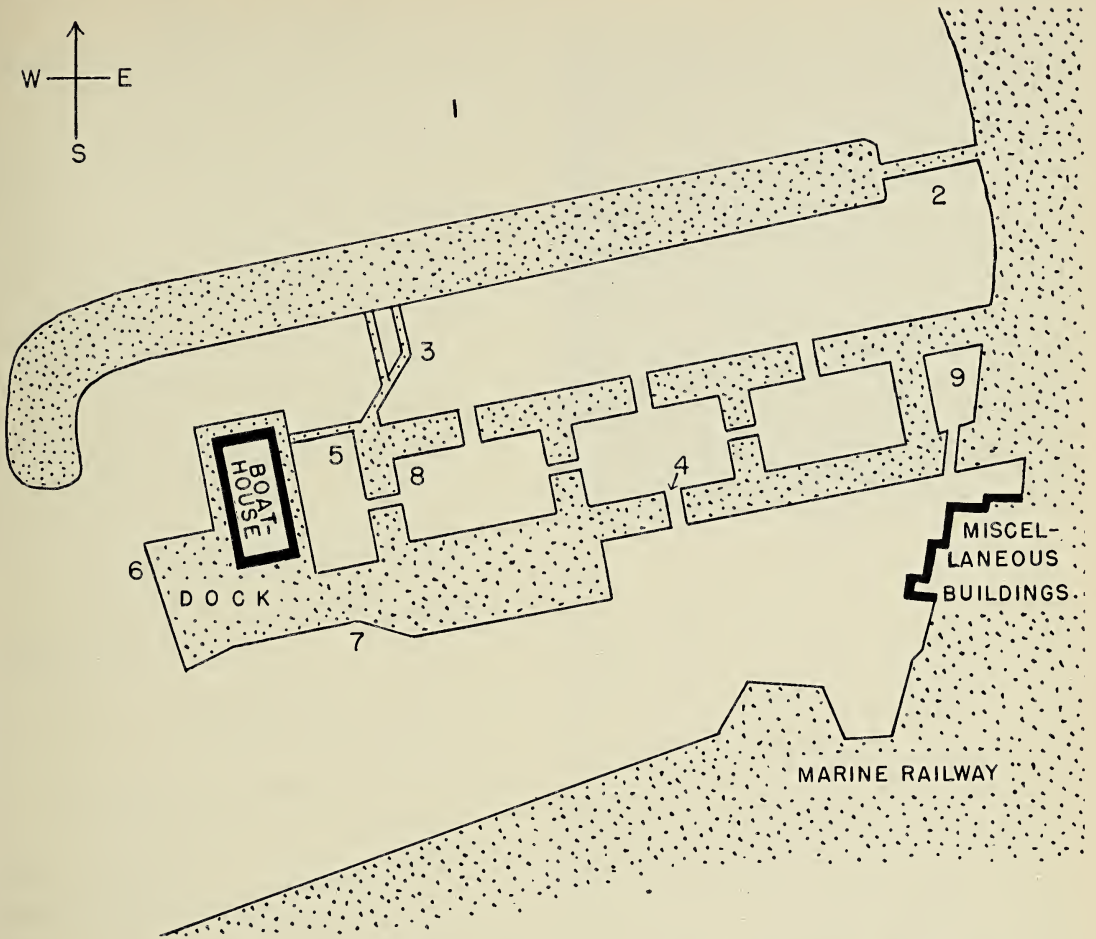


FIG. 2. Map of the vicinity of the Hawaii Marine Laboratory at Moku O Loe, showing by number six locations that are referred to, and three others for future reference.

ing sponges in all respects that are visible to the naked eye. Massive or branching sponges are easily discriminated, but such thin crusts as characterize the coral patches of Kaneohe Bay are perplexing. This locality furthermore contains especially numerous examples of the sponge-mimicking ascidians. The latter even contain spicules of the sort known as spherasters ( a central ball, covered with outward projecting, conical, spines). Quite a few sponges contain spicules of just this shape, but these are always siliceous in sponges, always calcareous in the ascidians. Some sponges have calcareous spicules, but these are never spherasters.

A probable identification of the commoner

sponges of Kaneohe Bay and vicinity may be made in the field by the key which is furnished below. Positive identification can only be made after microscopical study. Permanent mounts to show structure should be sectioned and preserved in balsam; but there are simpler methods available if permanent mounts are not required. Much structure can be ascertained by use of a dissecting-type stereoscopic microscope. One may slice the sponge in various directions and tease out small bits, using such a microscope. For spicule study one may take bits of the sponge, some from the surface and others from the interior, each bit about 3 mm. in diameter, put a few drops of concentrated fresh sodium

hypochlorite solution on the sample, add a cover slip and study, pressing on the cover slip with a dissecting needle to move the gas bubbles. Commercial bleaching solutions such as Clorox and Purex will do, but a more concentrated solution is preferable. Such a solution destroys the protoplasm and leaves the spicules obscured only by the myriad bubbles. These latter may be moved about so that the isolated spicules are revealed. For permanent mounts one may boil out a sample (on a slide) with about six drops of fuming nitric acid, later adding balsam and cover slip.

A few words about spicule nomenclature may be in order. Megascleres typically make up the framework of the sponges in which they occur and are always comparatively large, sometimes even visible to the unaided eye. Microscleres never make up the framework of a sponge and are almost always minute. Some have a distinctive shape, and when such a shape is found to be large, that spicule is still regarded as being a microsclere in spite of its size. Megascleres may have three or more rays diverging from a central point (triaxon, tetraxon, etc.) or, instead, may be monaxon. The latter may be sharp at both ends (oxeas) or at only one end (style). If rounded at both ends they are called strongyles; if swollen at both ends they are called tyloles. A tylostyle is swollen at one end, pointed at the other. The prefix "acantho" means spiny. Microscleres may be very thin rods (raphides), S- or C-shaped (sigmas), or archer's-bow-shaped (toxas). Some are asters, covered with long rays. These are termed euasters if all radiate from a point, but are called streptasters if the rays radiate from a rod or bar. Amphidisks or birotulates have a circular pattern at each end of a rod. Related forms called chelas are so elaborate that they require illustration; some resemble anchors. If both ends are alike, it is an isochela, but if the ends differ it is an anisochela.

## KEY TO GENERA

The commoner species occur in the genera marked with an asterisk.

1. No proper spicules present . . . . . 2  
Proper spicules present . . . . . 5
2. Spongin network present . . . . . 3  
Spongin network absent . . . . . 4
3. Fibers almost always clear . . . . .  
. . . . . *Spongia*\* p. 7  
Fibers full of debris . . . . . *Dysidea* p. 9
4. A few fibers present, no network . . . . .  
. . . . . *Pleraplysilla* p. 9  
No fibers present, dermal spongin  
present . . . . . *Hexadella* p. 10
5. Spicules of silica present . . . . . 6  
Spicules of calcium carbonate present . . . . . 24
6. Spicules rare, skeleton chiefly sand . . . . .  
. . . . . *Kaneohea* p. 23  
Spicules common . . . . . 7
7. Astrose spicules present . . . . . 8  
Astrose spicules absent . . . . . 9
8. Sponge spherical, no twice-bent  
oxeas . . . . . *Tethya*\* p. 30  
Sponge not spherical, twice-bent  
oxeas present . . . . . *Zaplethea* p. 32
9. Some spicules triaxon . . . . . *Plakortis* p. 33  
No spicules triaxon . . . . . 10
10. Ectosomal spicules the same as those  
of endosome . . . . . 11  
Ectosomal spicules different from  
those of endosome . . . . . 20
11. Larger spicules diactinal . . . . . 12  
Larger spicules monactinal . . . . . 15
12. Diacts are strongyles . . . . .  
. . . . . *Xytopsiphum* p. 11  
Diacts are oxeas . . . . . 13
13. A fine-mesh dermal network present  
. . . . . *Callyspongia*\* p. 12  
No such dermal net present . . . . . 14
14. Spicules oxeas and small toxas . . . . .  
. . . . . *Toxadocia*\* p. 16  
Spicules oxeas and raphides . . . . .  
. . . . . *Neoadocia* p. 15



15. Monacts chiefly styles (a few may have a slight "head") . . . . . 16  
     Practically all monacts clear-cut tylostyles . . . . . 18
16. No spicules except styles . . . . .  
     . . . . . *Hymeniacion*\* p. 27  
     Other spicules also present . . . . . 17
17. Anisochelas and sigmas also present . . . . .  
     . . . . . *Mycale*\* p. 24  
     Styles, isochelas, anisochelas, sigmas, toxas, and raphides present . . . . .  
     . . . . . *Zygomycale*\* p. 25
18. Spicules only tylostyles; sponge never boring into  $\text{CaCO}_3$  . . . . .  
     . . . . . *Terpios*\* p. 28
19. Oxeas and acanthomicrostrongyles also present; sponge usually confined to galleries in  $\text{CaCO}_3$  . . . . .  
     . . . . . *Cliona*\* p. 30
20. Dermal spicules spiny . . . . . *Naniupi* p. 18  
     Dermal spicules smooth . . . . . 21
21. Endosomal spicules spiny . . . . .  
     . . . . . *Myxilla* p. 17  
     Endosomal spicules smooth . . . . . 22
22. Microscleres only raphides . . . . .  
     . . . . . *Tedania*\* p. 21  
     Other microscleres present . . . . . 23
23. Microscleres are isochelas . . . . .  
     . . . . . *Damiriana*\* p. 13  
     Microscleres are amphidiscs . . . . .  
     . . . . . *Hiattrochota* p. 19
24. Spicules chiefly calcareous triaxons . . . . .  
     . . . . . *Leucetta*\* p. 34

#### DESCRIPTIONS OF SPECIES

##### *Spongia oceania* new species

Figs. 3, 4

The holotype of this species is designated as a dried specimen, U. S. National Museum, Register Number 22755. It was collected February 14, 1948, just north of the entrance to Hanauma Bay, from a depth of 8 meters. Further data as to the abundance of this sponge are given after the description.

The shape of *Spongia oceania* is irregularly massive. Its size is often greater than 10 cm. in diameter. As is the rule in this genus, the

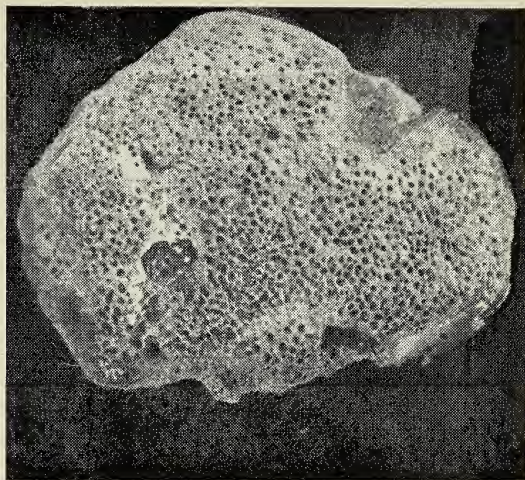


FIG. 3. Holotype of *Spongia oceania*,  $\times \frac{1}{2}$ .

exterior is normally jet black, the interior brown. Specimens that grow in the shade, however, fail to reveal the black color. The first ones that I found, from Moku O Loe, were dull brown externally, turning gray in alcohol. The consistency is very spongy as compared to other genera, but *oceania* is definitely less spongy than are most other species of the genus *Spongia*.

Its surface is most distinctive. Large areas are completely devoid of conules, and where these protrusions do occur they are only 0.1 to 0.2 mm. high, 4 to 6 mm. apart, and are vague. The oscules are 1 to 2 mm. in diameter. In a typical area of 10 square cm. I count 138 oscules; the average will certainly be close to 14 per square cm. on the upper surface of the sponge. There are, of course, very few on the sides, and none below. Many are only 2 mm. apart, center to center. These oscules in life are subject to at least partial sphinctrate closure, as are also the pores. The pores in spirit-preserved specimens are abundant, 40  $\mu$  in diameter, but may have been slightly larger when fully opened in life.

The ectosome of *oceania* is a typical *Spongia* dermis about 15  $\mu$  thick, full of heavily pigmented cells. The endosome is the usual dense reticulation. The flagellate chambers



are spherical, about  $25\ \mu$  in diameter. The abundant fibers consist of nearly opaque, typically rather granular spongin without foreign inclusions. They are  $15$  to  $30\ \mu$  in diameter and enclose meshes often about  $50$  by  $200\ \mu$ . The scarce ascending fibers are about  $60\ \mu$  in diameter, and contain a core of fragments of spicules from neighboring sponges.



FIG. 4. Fibers of *Spongia oceania* from a camera lucida drawing,  $\times 100$ . A, principal or ascending fiber; B, common fibers.

No other species of *Spongia* has such numerous oscules of such small average size. A few such small ones may occur here and there in other species but as a rule the oscules are large, often nearly  $10\text{ mm.}$  in diameter, and many centimeters apart. Only a few other *Spongia* specimens are as hard as *oceania*, and in each such case it appears decidedly possible that the hardness is due to some local environmental condition. The hardness of *oceania* may be a specific character. It would be interesting, however, to see if soft varieties, imported from elsewhere, would continue to grow soft in Hawaii. The commercial possibilities of *oceania* do not appear great, but they do exist.

The species name is given in respect to the location of this sponge near the center of the world's largest ocean.

The abundance of this species calls for special attention because it is almost, or perhaps could be, a commercial sponge. It is recorded that the ancient Hawaiians collected

and used dried specimens, but to only a slight extent. Wet specimens feel somewhat like the usual commercial sponges, and I have used a locally collected sponge in a very practical way in my laboratory. Yet even when wet it is somewhat difficult to compress, and when dry it is almost as stiff as wood. The commercial sponge *Spongia officinalis* variety *dura* from the West Indian region, known in the market as "hardhead," is much like *oceania* in consistency. The best Hawaiian sponges are scarcely third-grade by market criteria, but their ability to absorb and hold water (which may then be readily squeezed out) is quite good. They have a fairly small ratio of gross cavities, so that their chief fault is the unpleasant stiffness.

I first collected this species in Kaneohe Bay (at Moku O Loe) on December 22, 1947, but the specimens from this vicinity were all small, thin encrusting forms, ill suited to reveal the typical characteristics. Mr. Vernon Brock collected the type specimen by "skin diving" and reported that at the type locality the bottom for perhaps as much as several acres was thick with spongiars, scarcely a meter apart, and many of them were much larger than human head size. He brought up one specimen over  $40\text{ cm.}$  in diameter. It is curious to note that there is probably a greater bulk of this species in the Hawaiian Archipelago than the total bulk of all other shallow-water Hawaiian sponges. Reports came to me of vast windrows of this sponge cast on the beach after storms. On January 24 to 26, 1947, an unusually severe gale struck Hawaii and on January 28, I went almost entirely around the island of Oahu, examining beaches along the south, east (windward), and north shores. I found only a few small fist-size spongiars cast up. Almost nothing else was cast up, however, so presumably the wave action of this storm was of some peculiar nature so that it scoured material off the beach rather than depositing it. Extra big deposits of storm-dislodged sponges are



reported from the windward side of the island of Molokai, even masses 2 feet deep extending far along the beach. Reports came to me of large beds of *Spongia* north of the island of Maui and just north of, and also just south of, Kaneohe Bay. Dredging at the latter locality failed, however, to yield a single specimen. During May, 1948, I made a reconnaissance of the large island of Hawaii and found this species rather common along the south and west coasts, but did not similarly explore the turbulent, windward, northeast coast.

#### *Dysidea avara* (Schmidt) de Laubenfels

This species is represented to date by only a single specimen collected at Moku O Loe on January 10, 1948. This is now deposited in the U. S. National Museum, Register Number 22749. It was growing on the east side of the dock, near the concrete bridge which connects the dock with the island. It was at a depth of about 2 meters. This is location number 5 on the map.

This specimen is 6 by 7 by 9 cm., massive, and in life it was dull purple outside, brown inside. Its consistency is very spongy, but if dry it would doubtless, like others of the same species, become hard and brittle.

The surface is beset with conules about 2 mm. high and 1 to 8 mm. apart, usually 3 to 4 mm. apart. The oscules are 3 mm. in diameter and 2 to 3 cm. apart. The pores are 50  $\mu$  in diameter; about 10 or 14 such occur in each of numerous surface areas. Each such area is about 0.5 mm. in diameter, and represents a mesh in a subdermal reticulation of spongin fiber.

The ectosome consists of a thin dermis much perforated by pores as described. The endosome is fibro-reticulate. The flagellate chambers are 60  $\mu$  in diameter, sack-shaped (eurypylous). Both primary or ascending fibers and secondary fibers are loaded with foreign material, but a few fibers in the subdermal reticulation are free from detritus.

These latter are 20 to 40  $\mu$  in diameter. In the main fibers a few short spaces that are free of inclusions are 100  $\mu$  in diameter, but the abundant inclusions are often sand grains of 250  $\mu$  in diameter.

The species name *avara* was first used as *Spongelia avara* by Schmidt (1862: 29) for a Mediterranean species very much like this one from Hawaii. That *Spongelia* falls in synonymy to the earlier *Dysidea* is made clear by de Laubenfels (1932: 124) if not sooner; earlier authors had speculated that such might be the case. Very similar sponges are recorded from Australia by Lendenfeld (1889: 668) as *Spongelia distans* and are recorded from the Philippines, first by Wilson (1925: 476) as *Spongelia fragilis* and subsequently by de Laubenfels (1935: 327) as *Dysidea pallescens*. Burton (1934: 583) placed many species, including *pallescens*, *distans*, and *avara*, in synonymy with *fragilis*. In a monograph of the keratose sponges (de Laubenfels 1948: 142) I maintain the specific distinctness of *avara* as compared to *fragilis*, including *distans* with *avara*. The species *avara* is never as pale or grayish as *fragilis*, and consistently has a much coarser surface. In addition *fragilis* tends to have larger oscules, often at the distal ends of cylindrical branches. Occasional deformed specimens of *avara* may resemble equally rare deformed specimens of *fragilis*, thus leading to the belief that all are conspecific. *D. avara* appears to be common throughout the Old World, Europe to Australia, and is now recorded in mid-Pacific. *D. fragilis* is world-wide, being found even into the near Arctic.

#### *Pleraplysilla byalina* new species

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22754. It was collected January 10, 1948, in Kaneohe Bay at a depth between 1 and 2 meters, growing on dead coral.

This species formed an extremely thin encrustation, barely 100  $\mu$  thick at the thickest unless measured directly at the conules. It spread laterally for distances of several centimeters on the exceedingly irregular surfaces of the coral. It was possible to dislodge postage-stamp-sized pieces with some difficulty. In life the color was blue-gray, and the transparency of the whole sponge was noteworthy. The consistency of the flesh was softly colloidal, scarcely more firm than raw egg white. The fibers were stiffly elastic.

The surface of this sponge was decidedly conulose, with conules 3 to 7 mm. apart and about 2 mm. high. Neither oscules nor pores could be found in the preserved specimen. Doubtless they were almost or quite microscopic in life, and completely contracted in the alcohol or while the encrustation was being scraped off. The whole is so thin that no distinction can be drawn between ectosome and endosome; specifically there was no evident dermis or dermal specialization, merely the surface of the protoplasm.

Doubtless there was a basal plate of spongin. Certainly at intervals spongin fibers rose upward, perpendicular to the base. These fibers are of clear amber-yellow spongin with a central region that is densely packed with spicule fragments and fine sand.

This appears to be the third time that anyone has found this genus, which is separated from the somewhat more common *Aplysilla* by the occurrence of a central region in the fiber filled with foreign detritus. The first was on the north coast of France, as recorded by Topsent (1905: clxxxiv). He described his discovery as *Pleraplysilla minchini*. It differed from the Hawaiian specimen in being opaque and chocolate-brown in color. The second occurrence of the genus was recorded by George and Wilson (1919: 165) at Beaufort, North Carolina. This species, *Pleraplysilla latens*, was described as colorless, conules less than 1 mm. high; the distance between conules was not given. In 1946, I spent the

summer at Beaufort, but was unable to find a trace of *Pleraplysilla*. Of course it is an exceptionally inconspicuous sponge. The Hawaiian species is set off by color from *minchini* and in color and conule size from *latens*. The specific name selected refers to its transparency.

#### *Hexadella pleochromata* new species

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22748. It was collected January 10, 1948, in Kaneohe Bay at a depth of between 1 and 2 meters, growing on dead coral. It was also collected by dredging at 50 meters depth on the opposite side of Oahu, in the ocean south of Pearl Harbor, on February 19, 1948.

This species forms a thin encrustation not quite 1 mm. thick. In life the color is sulfur-yellow, but upon dying it turns purple. The consistency is fleshy, modified by the tough dermis.

The surface of this sponge was smooth, with scattered openings 25 to 60  $\mu$  in diameter. No distinction between exhalant and inhalant openings could be made.

The ectosome is a tough organic cuticle, giving no evidence of cellular nature but instead is almost certainly suitably called spongin. The endosome is completely askeletal, comprising only the protoplasmic sponge structures. The flagellate chambers are large, sack-shaped (eurypylous), 30 by 60  $\mu$  in size.

*Hexadella* was established by Topsent (1896: 119), like the preceding genus, for thin encrustations found on the north coast of France. He used two species names, *racovitzae* (the type) and *pruvoti*. Both were yellow, the only difference being that the former had rose-red tints. The two have long been regarded as conspecific but to clarify the literature, such reduction to synonymy is definitely made here. It is noteworthy that *racovitzae* does not turn purple on dying. The critical diagnosis of *Hexadella* concerns the



lack of mineral or fibrous skeleton but the presence of a tough spongin dermis.

Dendy (1905: 61) established *Hexadella indica* from India. This was red when alive, lamellate and folded, with peculiar surface openings called "chones." Burton (1926: 2) described *Hexadella kirkpatricki* from South Africa. This was gray, with papillate oscules, and erect habitus. Burton (1937: 43) described *Hexadella purpurea* from India. This was purple in life, not at all folded like *indica*, and the endosome contained much foreign detritus.

*Hexadella pleochromata* is sharply set off from the other species in the genus by its change of color from yellow to purple upon dying. On the other hand, exactly such a change is exhibited by one species of *Aplysilla*, one or two species of *Ianthella*, one undescribed species of *Thorectopsamma*, one undescribed species of *Hippiospongia*, and several species in *Verongia*. Thus it is a trait that is widespread in the families of the order Keratosa. It is clearly based on the occurrence of a pigment that has the properties of an indicator. It may be regarded as practically certain that in a sufficiently acid medium this pigment is yellow, whereas in a sufficiently alkaline medium it is dark purple. The chemistry involved is being worked out at Yale University for the related pigments in *Aplysilla* and *Ianthella*.

#### XYTOPSIPHUM new genus

This genus is erected in the family Desmacidonidae with the following species, *Xytopsiphum kaneohe*, as genotype. It should be emphasized that this is a genus with strongyles as megascleres and arcuate chelas for microscleres. In the type, the latter are peculiar, with greatly reduced clads.

The genus *Xytopsibis* de Laubenfels (1936: 54) has a description essentially like this one, and there are some sound reasons for arguing that the species *kaneohe* should be put in it. On the other hand, the type of

*Xytopsibis* was emphasized as being the sponge which Bowerbank (1875: 287) described as *Halichondria aspera*, from a specimen from the Malayan region. This might be considered fairly close to the Hawaiian faunal region, too. Were Bowerbank's description accurate, the matter would be simple. On May 26, 1948, however, Dr. Maurice Burton of the British Museum (Natural History) wrote me a personal letter stating that the type specimen of *aspera* was in his museum, a dried specimen, and that it is not at all as Bowerbank described it; instead it is a *Tedania*.

One might argue that because *aspera* does not fit the diagnosis of *Xytopsibis* it cannot go into that genus, is not and cannot be the type thereof, hence, that the following new species which does fit the diagnosis must become the type of *Xytopsibis*. Against this I will set the following considerations. The original generic designation said "*Xytopsibis* is established for genotype *Halichondria aspera* Bowerbank"; furthermore, the description mentioned chelas of two sizes, so that the Hawaiian sponge does not fit perfectly. It is here considered that *Xytopsibis* falls, with *aspera*, into synonymy to *Tedania*.

*Xytopsiphum* is not secure in its allocation to the Desmacidonidae. This family contains many genera that may be discovered, if adequate data about surface structure become available, to resemble more the Adociidae, or perhaps a new family between the older two. *Xytopsiphum* may go into this still hypothetical new family. Its closest relatives are now in the Desmacidonidae; these are *Plumocolumella* (megascleres oxeads, microscleres perhaps really like those of *kaneohe*, but the surface structure hispid) and closer still, *Xytopsaga*, whose megascleres are hastate tornotes, and whose microscleres are arcuate chelas. They are rather commonplace chelas whereas those of *kaneohe* are peculiar, with minute clads, as in *Plumocolumella*. On the island of Hawaii there occurs an un-

described species of sponge which I regard as congeneric with *kaneohe*; it is definitely closely related. Yet this undescribed sponge has somewhat commonplace arcuate chelas as its chief point of separation from *kaneohe*, and therefore it approaches the genus *Xytopsaga*. On the other hand, *Xytopsaga* has much coarser structure and seems to be confined to the Antarctic region.

The generic name is based upon a modification of the older name *Xytopsibis*.

*Xytopsiphum kaneohe* new species

Fig. 5

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22742. It was collected January 10, 1948, at Moku O Loe, in the shadow of the walk along the south side of the series of small artificial lagoons, east of the dock, depth about 1 meter, location number 4 on the map. Another specimen was collected on September 27, 1947, in Waialua Bay, Oahu, at a depth of about 6 meters, on dead coral.

Both specimens were thin encrustations, 1 to 5 mm. thick, covering areas of between 10 and 20 square cm. The type was very dark, almost black, but the color promptly dissolved out (and disappeared) in alcohol, leaving a pale grayish-pink specimen. Many sponges have a melanotic pigment, but it is quite resistant to alcohol. It may be that the dark hue of this specimen was due to some foreign material on the surface. The other specimen was reddish-brown, mottled. In alcohol it has become the same dull color as the type. The consistency is soft.

The surface of this species is relatively smooth, and the pores are not evident, probably due to rapid closing. On the Waialua specimen there is a surface hole, 0.5 mm. in diameter, with slightly raised rim, that may or may not be an oscule. Otherwise (and chiefly) the species is lipostomous, as are many thin encrusting sponges.

The ectosome is semidetachable, rendering family allocation of the genus difficult. There are many spicules tangentially placed in the dermis, but these are the same as the megascleres of the interior. The endosome is dense, with spicule tracts that range up to  $50\mu$  in diameter, 150 spicules per cross section, spongin dubiously present.

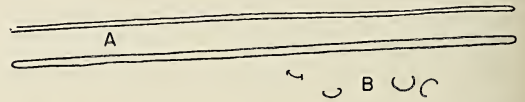


FIG. 5. *Xytopsiphum kaneohe*, spicules, from a camera lucida drawing,  $\times 400$ . A, strongyles; B, sigmoid microsccleres, probably reduced arcuate isochelas.

The megascleres are straight strongyles, 3 to  $4\mu$  thick, 200 to  $210\mu$  long. In one place in the Waialua specimen there are deformed but otherwise commonplace arcuate chelas; their absence from the rest of the specimen would indicate that they are foreign. In both specimens there are very abundant peculiar microsccleres that are to be regarded as arcuate chelas, but the clads are so small that one obtains a first impression that these are sigmas. On the other hand, they are not at all contorted, as most sigmas are, but lie in one plane. These distinctive microsccleres have a chord length of  $15\mu$  in the Waialua specimen, but of only  $10\mu$  in the type specimen.

The species name given refers to the type locality.

*Callyspongia diffusa* (Ridley) Burton

Fig. 6

This species was first studied in Hawaii on September 10, 1947, at the dock at Moku O Loe (location 6, Fig. 2). This specimen is deposited in the U. S. National Museum Register Number 22741. The species was found again on September 27, 1947, at Waialua Bay, and thereafter several times in various places in Kaneohe Bay, where it is



moderately common. The shape is typically ramose, but juvenile specimens are temporarily encrusting. The branches are about 6 mm. in diameter, and often more than 12 cm. high. Three to five branches occur in the average mass. The color, in life, is dull drab with more or less lavender tinges; the more the sponge was exposed to light, the more lavender it shows. The consistency is very spongy.

The surface is superficially smooth. The pores in the protoplasmic dermis are often  $40\ \mu$  in diameter. The oscules are 4 to 6 mm. in diameter, with raised rims often 3 mm. high.

The surface is covered by a network of fibers which are smaller than the fibers of the endosome and form smaller meshes. This is quite typical of *Callyspongia*. There is some ground for regarding the Hawaiian specimens as representing a new species, because unlike any other *Callyspongia* there is no coarser dermal net to include the finer one in its meshes; this is offset by the fact that there is such a net just below the surface. The endosome is a typical callyspongoid fibroreticulation.

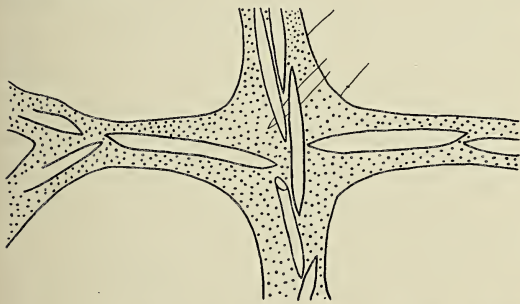


FIG. 6. *Callyspongia diffusa*, bit of the endoskeleton,  $\times 320$ , showing spicules (oxeas) in spongin fibers. From a camera lucida drawing.

The dermal fibers are 10 to  $15\ \mu$  in diameter, contain a single row of spicules, and form meshes that are 60 to  $100\ \mu$  in diameter, usually about  $75\ \mu$ . The protoplasmic dermis is in this same plane. The endosomal fibers are 25 to  $35\ \mu$  in diameter in the

Kaneohe specimen, about  $40\ \mu$  in diameter in the one from Waialua Bay. In the latter there are several rows of spicules in some ascending fibers; in the Kaneohe specimen all the fibers have only the uniserial core of spicules. The endosomal meshes are 50 to  $500\ \mu$ , often about  $200\ \mu$ , in diameter, more or less rectangular. The spicules are oxeas, rather hastate; typical sizes are 4 by 100, 5 by 90, 6 by  $75\ \mu$ . In one specimen I found one toxa  $25\ \mu$  long. This is probably accidental, but is thought provoking in view of the similar color and shape of *Toxadocia* (p. 16) which has many toxas. *Toxadocia*, however, has a different sort of ectosome from *Callyspongia*.

Many species of *Callyspongia* are tubular in shape, with thin walls around the central hollow, which has a large distal opening. The type of the genus, *C. fallax*, is solid cylindrical, however. The species *diffusa* is perhaps best characterized by its relatively thick spicules. It was first described as *Cladochalina diffusa* by Ridley (1884: 183) from the Indian Ocean. It was subsequently recorded as *Cladochalina elegans* by Lendenfeld (1887: 770) from South Australia, as *Chalina pulvinatus* by Lindgren (1897: 481) from the Malay region, as *Ceraochalina reticarmata* by Dendy (1905: 152) from India. It is discussed, with synonymy, by Burton (1934: 541).

#### DAMIRIANA new genus

This genus is erected in the family Phorbasidae with the following species, *Damiriana hawaiiiana*, as genotype. It should be emphasized that this is a genus with a special dermal skeleton of tylotes over an endosomal skeleton of oxeas, with arcuate chelas among the microscleres.

Within this family the genus *Damiriella* seems fairly close to *Damiriana*; all the other genera are widely different. None of the others has dermal tylotes, although such spiculation is common in the family Myxillidae.

All the others, with the dubious exception of *Iophonota*, do have echinating spicules. *Damiriella* has principal spicules that are strongyies whereas *Damiriana* has oxeas, otherwise the two are close. *Damiriella* is a rare genus, with only one species, itself rather rare, reported only from the Mediterranean coast of France.

The name *Damiriana* is selected to show plainly the resemblance to *Damiriella*.

*Damiriana hawaiiiana* new species

Fig. 7

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22737. It was collected September 10, 1947, at Moku O Loe, in shallow water near the pier. It has been common at location 3 (Fig. 2), just inshore of the bridge over the long lagoon. It seems to grow very slowly. Several times during 1947 and 1948 bits were removed for study, and by just that much the total quantity present seems to be semipermanently reduced. In the fall of 1948 what might be a total of one or two handfuls remained.

In August, 1945, R. W. Hiatt carried out an extensive ecological survey on the south shore of the island of Hawaii, at a nearly inaccessible and therefore relatively natural and undisturbed region called Halape. He found at least one specimen of *Damiriana* growing on coral in a very exposed situation, quite in contrast to the quiet lagoon in Kaneohe Bay.

On May 19, 1948, at Kailua on the north Kona coast (west side) of the island of Hawaii I found a small, somewhat aberrant specimen of this species growing just barely below low tide.

*Damiriana hawaiiiana* comprises first an amorphous basal region, often about the size of a hen's egg. From this, one or a few branches arise, little-finger size and shape. The color is a brilliant vermilion-red, and the consistency is soft, easily torn. The Kailua

specimen was dull orange rather than flame-colored.

The surface is superficially smooth. The oscules may be terminal or lateral, may number six or more per specimen, and open as wide as 6 mm. They are conspicuously closable by a membrane which is pulled inward from all sides, maintaining the circular outline of the shrinking aperture. At least 5 minutes are required for complete oscular closure. The surface is perforate with gross pores, which in some places almost touch each other, elsewhere are far apart. Each of these, about 1 mm. in diameter, is in turn filled with a finer network, the meshes of which are barely  $150\ \mu$  in diameter, 20 to 30 such openings per sieve. In places there are scattered pores, not so grouped, each about  $40\ \mu$  in diameter.

The ectosome is a definite dermis, less than  $100\ \mu$  thick, with its special spicules tangentially placed. The endosome is somewhat like "crumb of bread," with its special spicules chiefly in confusion, or in vague tracts about  $100\ \mu$  in diameter. They often are placed so as to outline chambers, as in the genus *Myxilla*. The flagellate chambers are spherical, 25 to  $40\ \mu$  in diameter. There is abundant colloidal material present.

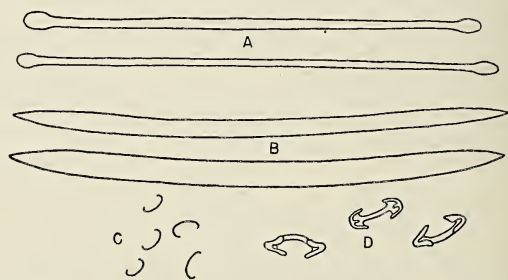


FIG. 7. *Damiriana hawaiiiana*, spicules, from a camera lucida drawing,  $\times 333$ . A, dermal tylotes. B, endosomal oxeas. C, sigmas. D, arcuate isochelas.

The ectosomal megascleres are tylotes, usually about 5 by  $200\ \mu$ , although in one specimen, otherwise typical, they were only 4 by  $170\ \mu$ . This is a minor difference. The endosomal megascleres are oxeas, usually about



8 by 200  $\mu$ , but sometimes 9 by 230. A few thicker, shorter ones, 12 by 180  $\mu$ , may be found, for example. The microscleres are of two sorts. There are abundant, commonplace, arcuate isochelas, 27  $\mu$  long. In the aberrant Kailua specimen there were also some only 15  $\mu$  long. A second category of microscleres appears to be a sort of sigma. It is C-shaped rather than S-shaped, is in one plane, not contorted. This suggests that it might be a reduced chela, and accordingly a search was made with immersion microscopy for traces of clads. At least one inward pointing clad is certainly present, perhaps three. The difficulty of being sure is due to the size of this spicule. Its chord length is 13  $\mu$ , its diameter 1  $\mu$ , the clad or clads are less than 1  $\mu$  in length, and at the widest about a third or a fourth of a micron in diameter, tapering to a point.

The species name is given in honor of Hawaii.

#### NEOADCIA new genus

This genus is here erected in the family Adociidae, with the following species, *Neoadocia mokuoloea*, as genotype. It should be emphasized that this is a genus with an ectosomal skeleton of tangentially placed oxeads, overlying an endosomal skeleton of oxeads, with raphides as microscleres. This is like *Adocia* except for the addition of raphides; it is set off from all other genera in the family by the possession of these microscleres.

The generic name is selected to show the close relationship to the genus *Adocia*.

#### *Neoadocia mokuoloea* new species

Fig. 8

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22745. It was collected September 10, 1947, at a depth of about 2 meters, near the dock at Moku O Loe (location 6, Fig. 2). Only the single speci-

men was found. I have repeatedly searched for others but without success.

The specimen is a mass 2 by 3 by 3 cm. Two holes go right through it, perhaps caused by foreign objects about which it grew; one of these is 3 mm. and the other is 9 mm. in diameter. The color in life was golden-yellow for all the interior and much of the exterior, but externally there were rosy-red patches. The consistency is very soft.

The surface is exceptionally punctiform. It is liberally perforated by apertures 1 mm. in diameter, more than 20 per square cm. of surface, on all surfaces except the surface of attachment. It is not clear which of these apertures are inhalant and which exhalant, unless it may be that all are pores, and the two large openings mentioned above may be the oscules. It would be interesting to have additional specimens and so be able to ascertain more of the structure of this species.

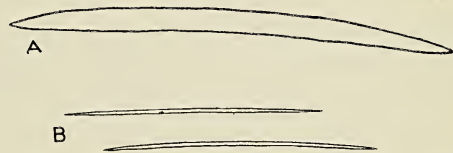


FIG. 8. *Neoadocia mokuoloea*, spicules, from a camera lucida drawing,  $\times 444$ . A, megasclere (oxea). B, microscleres (microxeas), or raphides.

The ectosome contains a tangent dermal skeleton of smooth diacts, over subdermal spaces. The endosome is cavernous, with an isodictyal reticulation of smooth diacts and few or no spicule tracts at all. The megascleres are all smooth oxeads, 6 by 120 to 6 by 135  $\mu$ . The microscleres are commonplace raphides, about 0.5  $\mu$  thick, but upwards of 100  $\mu$  long.

*Adocia baeri* occurs in the Philippine Islands. It was first described as *Reniera implexa* variety *baeri* by Wilson (1925: 398) and made a species by de Laubenfels (1936: 328). This *Adocia* is very different from *mokuoloea* in appearance, being nearly black. It contains a few very thin spicules, but these

may merely have been juvenile forms of the megascleres, inasmuch as they are uncommon. There seems to be no way to discriminate between such immature forms and clear-cut raphides, unless the latter are so numerous that it is unlikely that they are juveniles. If it should happen, as I believe unlikely, that *baeri* has genuine raphides, then it should be transferred from *Adocia* to *Neoadocia*. This transfer is not here made.

The name of this new species is derived from its type locality, the island of Moku O Loe.

### *Toxadocia violacea* new species

Fig. 9

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22752. It was collected November 3, 1947, at Moku O Loe, at a depth of 1 meter, in the long pool near location number 3 in Figure 2. This species was also found growing in numerous places on dead coral throughout Kaneohe Bay, but not on the leeward side of Oahu. On the island of Hawaii I found it in at least two places near Hilo, which is on the windward side of that island.

This species is basically encrusting, but the numerous oscules are raised on little hillocks about 1 cm. high. Some projections are so long (15 mm.) but so narrow (3 mm.) as to resemble fistules. Few colonies reach the size of the palm of the hand or a basic thickness of as much as 1 cm. The color is a vivid violet and the consistency is soft and fragile.

The surface of *Toxadocia violacea* is smooth, provided with a translucent dermis over extensive subdermal cavities. The pores in this dermis are abundant, contractile, about 30  $\mu$  in diameter. The openings that lead down from the floor of the subdermal cavity are rather more conspicuous than those in the dermis, being readily visible through it. They are less numerous and are about 150  $\mu$  in diameter. The oscules are about 3 mm. in

diameter, and are often raised 8 to 16 mm. above the surface on rounded projections.

The dermal membrane is full of spicules tangentially arranged, but in little more than one single layer. The endosome is microcavernous, permeated by an isodictyal reticulation of spicules.

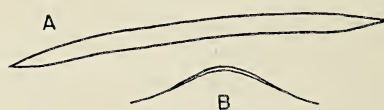


FIG. 9. *Toxadocia violacea*, spicules, from a camera lucida drawing,  $\times 444$ . A, oxea. B, toxa.

All the megascleres are smooth oxeas, about 4 by 120  $\mu$ . A few are larger, especially in the specimens from Hilo, where a size of 7 by 140  $\mu$  is sometimes reached. The microscleres are toxas, 1 by 60  $\mu$ . Some thin, straight spicules may be raphides, or juvenile megascleres, or merely edgewise views of toxas; they are not regarded as worthy of emphasis.

There are seven other species which have been assigned to the genus *Toxadocia*. Two, *toxius* and *toxophorus*, are East Indian, and one might expect them to be the most like this Hawaiian species, but such is not the case. Each has, for example, a very peculiar type of toxa which differs from those of all others in the genus. Two species from the tropical Atlantic, *abbreviatus* and *tener*, have megascleres that are many times larger than those of the Pacific species. One from Great Britain, *fallax*, has large spicules, but not nearly so large as those from farther south. There are two Arctic species, *primitivus* and *proximus*, and these have still smaller megascleres, and approach closest of all to the Hawaiian *Toxadocia*. Their toxas are much larger, however, and they and all other hitherto described members of this genus are recorded as yellow in color. Emphasis is laid here on the spicule differences and, particularly, on the color. The species name



*violacea* is derived from the violet hue of this sponge.

*Myxilla rosacea* (Lieberkühn) Schmidt

Fig. 10

This species is represented in the fauna of Hawaii by only two known specimens; both were collected at Moku O Loe in Kaneohe Bay. The first specimen was taken September 10, 1947, at a depth of 1 or 2 meters, on pilings at the dock (location 6, Fig. 2). This is deposited in the U. S. National Museum, Register Number 22734. A second was found January 10, 1948, in the sluice-way from one of the small lagoons (location 4, Fig. 2).

This sponge is massive. Our specimens are each fist-size, but much of the bulk is due to contained lumps of dead coral. The color in life is bright orange-red, paler in the interior. The consistency is slightly spongy, not especially remarkable. The surface is slightly and irregularly lumpy. There is a conspicuous translucent dermis pierced by microscopic contractile pores; through it the larger canals that lead into the sponge from the floor of the subdermal space are easily seen. These openings are about 0.3 mm. in diameter and 1.2 mm. apart. The oscules are few and scattered, about 6 mm. in diameter, and closable by very thin membranes.

The ectosome is packed with special dermal spicules arranged tangentially. The endosome is cavernous, "crumb of bread" type, with the skeleton in "log cabin" or modified isodictyal arrangement about small gross chambers.

The ectosomal spicules are smooth-shafted tornotes; their ends are just faintly microspined, their size about 3 by 160  $\mu$ . The endosomal spicules are acanthostyles, 8 by 140  $\mu$ . The microscleres include anchorate isochelas, approaching the unguiferate type but only 15  $\mu$  in total length, and also commonplace sigmas, 18 to 30  $\mu$  in chord length.

This species was first described from Europe, as *Halichondria rosacea*, by Lieberkühn (1859: 521). It was transferred to *Myxilla* (genotype) by Schmidt (1862: 71). It is abundant throughout Europe, on both the Mediterranean and Atlantic coasts, but appears to be absent from the Americas.

The European specimens and these from Hawaii agree rather closely. The former have isochelas that are often nearly twice as large as those of the latter, but this is scarcely a specific difference in view of the other similarities.

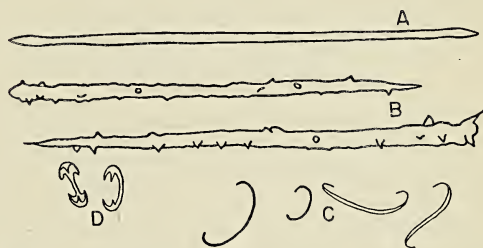


FIG. 10. *Myxilla rosacea*, spicules, from a camera lucida drawing,  $\times 444$ . A, dermal tornotes. B, endosomal acanthostyles. C, sigmas. D, anchorate isochelas.

In reviewing the very numerous species of the genus *Myxilla* with a view to identifying the Hawaiian specimen, various items become noteworthy. The genus *Burtonanchora* de Laubenfels (1936: 94) was established for certain species formerly in *Myxilla* but differing chiefly in that they have only smooth spicules, and thus passing over into the family Tedaniidae. Perplexing intermediate forms, having spicules that are only very slightly spined, exist; yet for convenience, if nothing else, the division is worth maintaining. The following additional species are now taken out of *Myxilla* to go into *Burtonanchora*: *M. acribria* de Laubenfels, *M. cribrigera* Ridley and Dendy, *M. mollis* Ridley and Dendy, and *M. novaezealandiae* Dendy. Two species, *D. inaequalis* and *D. simplex*, first put in *Dendoryx* by Baer, are also placed in *Burtonanchora*.

Four others appear to require transfer from *Myxilla* into the related genus *Lissodendoryx*. They are *M. bebringensis* Lambe, *M. cratera* Row, *M. firma* Lambe, and *M. pygmaea* Burton.

Topsent (1893: xxiv) described a sponge from the Mediterranean coast of France as *Myxilla arcitenens*. The megascleres and chelas are like *Myxilla*, but unlike this genus there are not (as usual) sigmas, and there are (as never in *Myxilla*) raphides and toxas. This is clearly not *Myxilla*. If there were no chelas it would fit *Achiliderma*. Because there is no genus now set up for this sponge, a new one is required, and is established as:

#### QUINTOXILLA new genus

This genus is assigned to the family Myxillidae, genotype *Myxilla arcitenens* Topsent. The holotype location is unknown to me; Professor Topsent told me personally that he rarely kept or deposited specimens. This is a genus with smooth dermal diactinal or sometimes inequidended spicules, and a principal skeleton of acanthostyles. The microscleres are isoschelas (presumably, but not certainly, anchorate) and toxas. Raphides may be among the microscleres, but this is not emphasized here. The name is arbitrary, not descriptive, suggested however by the emphasis upon the toxas of the spiculation.

#### NANIUPI new genus

This genus is erected in the family Myxillidae, subfamily Grayellinae, with the new species *Naniupi ula* as genotype. It should be emphasized that this is a genus with ectosomal acanthoxeas, endosomal smooth styles, and echinating acanthostyles. The microscleres include arcuate chelas. The genotype also has peculiar sigmoid microscleres. The genus name is derived from the native Hawaiian language, "nani" meaning beautiful and "upi" meaning sponge.

The subfamily Grayellinae is characterized by spiny diacts over smooth monacts. The

type genus, *Grayella*, has similar ectosomal acanthoxeas to those of *Naniupi*, as very few sponges do, but the endosomal spicules of *Grayella* are smooth tylostyles with no echinating spicules or microscleres. Brøndsted (1932: 14) described a sponge from east of Iceland as *Grayella akraleitae*. This has a spiculation of lumpy styles echinated by acanthostyles, with arcuate chelas as microscleres. This cannot be a *Grayella*, but belongs in the family Microcionidae in which, however, a new genus is required for its reception, and is here established as:

#### RAMOSICHELA new genus

This genus is assigned to the family Microcionidae, genotype *Grayella akraleitae* Brøndsted. The location of the holotype is not known to me. This is a genus for sponges with a principal spiculation of styles not smooth, in tracts that are echinated by acanthostyles; there are also arcuate isochelas. Within this family all the other genera have one or more categories of smooth megascleres except the genus *Ramoses*, which has no microscleres but is otherwise much like *Ramosichela*. *Ramoses* is exclusively Antarctic and sub-Antarctic whereas *Ramosichela* is Arctic or sub-Arctic. The genus name is derived from that of this related genus, *Ramoses*.

To continue with an analysis of the subfamily Grayellinae, de Laubenfels (1936: 88) puts *Crellomyxilla* here, but upon further consideration it is thought preferable to transfer this genus to the family Microcionidae, subfamily Yvesiinae. *Tethyspira* has been put in the Grayellinae with some doubt, and is, still doubtfully, left there. It has small acanthostrongyles that may be regarded as dermal; its main spicules are large smooth styles. A fourth genus belongs in this subfamily, on the basis of published descriptions, but as it too is unnamed it is here named as follows:



## QUINDESMIA new genus

This genus is assigned to the family Myxillidae, subfamily Grayellinae, genotype *Hymedesmia inflata* Bowerbank (1874: 245, pl. 79). The holotype is probably in the British Museum of Natural History. This is a genus for sponges with special ectosomal acanthoxeas and endosomal smooth monaxons echinated by acanthostyles, but without microscleres. It is reported only from Great Britain and is evidently quite rare. The name is arbitrary rather than descriptive.

Thus it appears that there are now four genera in the Grayellinae, of which *Naniupi* is the only one to have microscleres.

*Naniupi ula* new species

## Fig. 11

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22740. It was collected January 10, 1948, in Kaneohe Bay, at a depth of about 2 meters, growing on dead coral. On February 19, 1948, a similar specimen was dredged from a depth of about 50 meters, in the open ocean about 3 kilometers south of Pearl Harbor, on the opposite side of Oahu from Kaneohe Bay.

This rather uncommon sponge is a paper-thin encrustation, spreading indefinitely laterally. The type specimen came from a colony that covered an area about as large as a human hand, of very irregular outline due to the deeply sculptured mass of dead coral on which it grew. The color in life is a distinctive vivid carmine-red. The consistency is obscured by the extremely thin habitus.

The surface of *Naniupi ula* is smooth and lipostomous. The ectosome is a well-marked dermis, packed with a felted mass of tangentially arranged acanthoxeas. The endosome is dense, with its spicules in some confusion.

The special dermal acanthoxeas are about 4 by 110  $\mu$ . The endosomal megascleres are chiefly smooth styles about 4 by 190  $\mu$ . A few of these are pseudoxeas. In the deepest portions are a few echinate spicules, acan-

thostyles 7 by 130  $\mu$ . The principal or only microscleres are abundant, rather typical arcuate isochelas, 21  $\mu$  in total length. At least in the type specimen a few other spicules occur that seem, at first glimpse, to be microscleres. They are only about 1.5  $\mu$  thick, 80  $\mu$  long, very faintly microspined, and four times curved like two S-shaped sigmas end to end. There are, however, other similar spicules that are nearly straight, and these

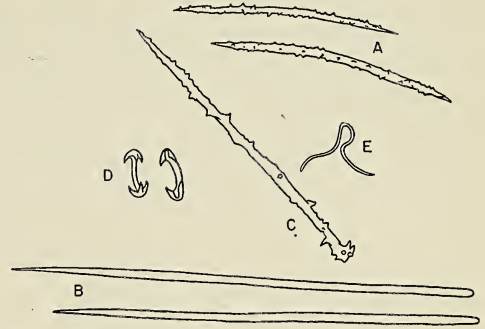


FIG. 11. *Naniupi ula*, spicules, from a camera lucida drawing,  $\times 333$ . A, dermal acanthoxeas. B, endosomal styles. C, echinating acanthostyle. D, arcuate isochelas. E, peculiar contort microsclere.

latter give evidence of being juvenile forms of the dermal acanthoxeas. The much curved spicules may be malformed examples of the same juvenile sort, but their occurrence is noteworthy. As additional specimens are found, this type of spicule should be looked for. I do not find them in the specimen collected south of Oahu.

The species name is derived from the native Hawaiian word for red, because of the brilliant color of this species.

## HIATTROCHOTA new genus

This genus is erected in the family Tedaniidae with the following species, *Hiattrochota protea*, as genotype. It should be emphasized that this is a genus with smooth strongyles as special ectosomal spicules, smooth styles as endosomal megascleres, and birotulates or amphidiscs among the microscleres, without chelas.

The genus *Iotrochota* may be regarded as a sort of nomenclatorial parent for all the marine Demospongiae having amphidiscs. Such spicules are common in the fresh water sponges (subfamily Meyeniinae) and in the order Amphidiscophora of the Hyalospongiae. As more and more species were put in *Iotrochota* for this reason, it became evident from their other characteristics that they actually belonged to several families. The type of *Iotrochota* (*birotulata*) is in the Desmacidonidae. In 1936 de Laubenfels took out many species, establishing from them the genera *Hymetrochota* and *Iotroata* in the Myxillidae, and *Iotaota* in the Tedaniidae. *Hiattrochota* is also in this latter family. The two myxillids have megascleres typical of that family; *Hymetrochota* has only amphidiscs for microscleres, *Iotroata* also has unguiferate chelas. Of the tedaniids, *Iotaota* matches the latter, with both amphidiscs and unguiferate chelas as well as megascleres typical of the family. *Hiattrochota* matches *Hymetrochota*, with only amphidiscs as microscleres, but megascleres typical of Tedaniidae.

The terminus of the new generic name follows the pattern as used for the comparable genera, but the distinctive prefix is given in honor of the eminent zoologist, Robert W. Hiatt.

*Hiattrochota protea* new species

Fig. 12

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22750. It was collected December 22, 1947, at Moku O Loe, at a depth of about 1 meter, in a sluiceway (location number 4, Fig. 2). Another specimen was collected May 16, 1948, at Kaalualu, near the south end of the island of Hawaii. Yet a third slightly different specimen was collected May 17, 1948, at Honau-nau on the Kona coast of the island of Hawaii.

This species is massive, about fist-size, and in life is velvety black. The spirits in which it is preserved are stained dark brown, but the sponge retains its hue. The consistency is somewhat elastic, not remarkable.

The surface is rather smooth, most of the pores having quickly contracted. A few openings about 1 mm. in diameter are dubiously regarded as unclosed pores. The oscules are 1 to 3 mm. in diameter and characteristically each is situated at the summit of a rounded dome or lobe, more than 1 cm. in diameter, but only about half as high.

The ectosome consists of a definite dermis over subdermal spaces, but is much less flesh-

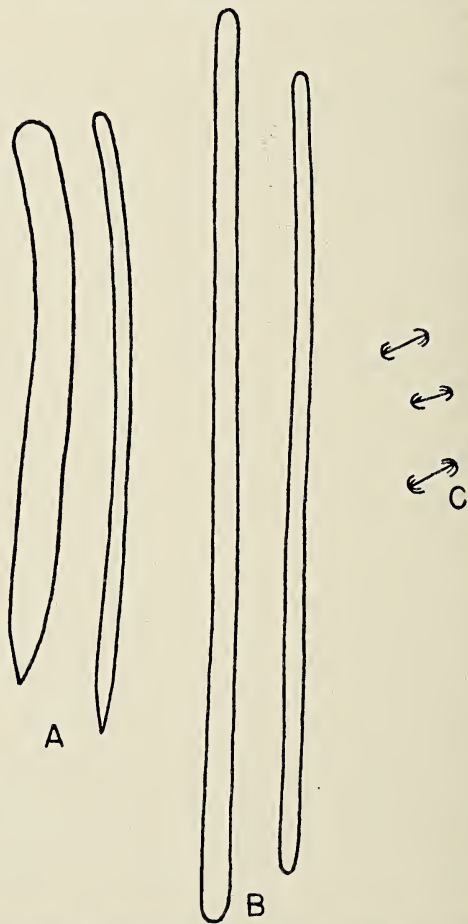


FIG. 12. *Hiattrochota protea*, spicules, from a camera lucida drawing,  $\times 666$ . A, endosomal styles. B, ectosomal strongyles. C, amphidisc or birotulate microscleres.



like than that of *Iotrochota*. The endosome is microcavernous with a skeleton that approaches the isodictyal condition, very much as in *Tedania*. There are a few vague spicular tracts, about  $50\ \mu$  in diameter in the type specimen but somewhat more than twice as thick in the second specimen. The latter grew on the beach of the open ocean, whereas the type was in calm water; this probably accounts for the difference.

The ectosomal spicules are smooth strongyles 3 by 140 to 6 by 205  $\mu$  in size. The endosomal spicules are smooth styles 7 by 135 to 10 by 180  $\mu$  in size. Both sorts are consistently a little larger in the Kaalualu specimen. Both sorts are somewhat thicker, up to 12  $\mu$ , in the Honaunau specimen. The microscleres are amphidiscs. Their length is 12 to 13  $\mu$  in the type specimen, 15  $\mu$  in both others. There are often only four clads at each end in those of the type specimen, usually more clads in the corresponding spicules of the other two specimens. In the type specimen the clads are less strongly recurved. In the Honaunau specimen, as in many hyalospongoid amphidiscs, the shaft is visibly spiny.

The species name is given because this is the first of the genus.

*Tedania ignis* (Duchassaing and Michelotti)  
Verrill

Fig. 13

This species is very common throughout the shallow waters of Hawaii including Kaneohe Bay. It is represented by a specimen collected at Moku O Loe from coral, near the pier (location number 6, Fig. 2). This specimen is deposited in the U. S. National Museum, Register Number 22744.

This species is basically encrusting, with the oscules often so elevated that chimneys as tall as 4 to 7 cm. result, yet these chimneys are usually less than 1 cm. in diameter, hollow, and thin-walled. Specimens are sometimes as large as a hand, more often somewhat

smaller. The color is bright vermillion where the sponge tissue grew in brilliant illumination, but more orange, even to yellow, in proportion to the amount of shade in which the sponge grew. The consistency is soft and the sponge easily torn or compressed.

The surface is smooth, with abundant, very contractile pores. The oscules are from 2 to 7 mm. in diameter, often raised in the form of tubes. The ectosome is a definite dermis, over subdermal spaces, and is packed with special spicules, not always horizontal but instead in many orientations; some clusters are actually perpendicular to the surface. The endosome is finely cavernous, somewhat "crumb of bread" style, with its spicules in quite confused arrangement.

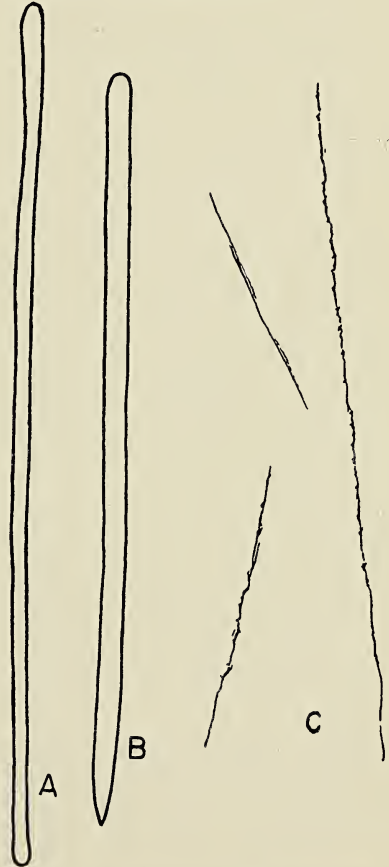


FIG. 13. *Tedania ignis* (?), spicules, from a camera lucida drawing,  $\times 666$ . A, dermal tornote. B, endosomal style. C, microspined raphides.

The special dermal spicules are usually regarded as tylotes, but the ends are so minutely enlarged that the spicule at first seems to be a strongyle and often really is a strongyle. It is rather that there is a very slight constriction near the end of each spicule than that the end is actually swollen. On each extreme tip of these spicules there are a number of very fine spines. These spicules nearly all range in size between 3 by 180 and 4 by 210  $\mu$ . The principal spicules are smooth styles, often curved a little, and range from 6 by 160 to 8 by 210  $\mu$ . The abundant microscleres are peculiar microspined raphides, usually less than 1  $\mu$  in diameter, but occasionally as thick as 2  $\mu$  with total lengths up to at least 200  $\mu$ .

Within the genus *Tedania* there are some 45 names, besides others that have been transferred to other genera. Some of the 45 are clearly synonyms, but others arouse serious questioning. There are some well-marked differences. One group of three or four species has two distinct categories of microscleres. On the west coast of North America two species (or is it all one?) have tylostyles instead of styles for principal spicules. Some deep-water species have enormous spicules and distinctive, symmetrical habitus. There remain about 20 species that differ in color and in having spicules a little larger or smaller. Burton (1932: 344) and also Burton and Rao (1932: 353 and following) argue that all these are conspecific and call them all *Tedania nigrescens*, which then would become an amazingly cosmopolitan species. Perhaps some further analysis is in order, and, in particular, color may be quite significant.

The genus *Tedania* was established by Gray (1867: 52) for *Reniera digitata* Schmidt (1862: 75) and *Reniera ambigua* Schmidt (1864: 39). The former was shown to be a synonym of *Reniera nigrescens* Schmidt (1862: 74) and the type is assumed by Burton and others to be called *nigrescens*.

This designation was made official by de Laubenfels (1936: 89). Topsent (1939: 5) pointed out, however, that *digitata* and *nigrescens* both fall to the earlier *Halichondria anhelans* Lieberkühn (1859: 522). This species, under various names, is well known from the Mediterranean, where it seems to be the only *Tedania*. It is regularly and consistently described by the various authors as being black or nearly so; some say very dark blue, some say very dark green. I have not found these colors in the field or in the literature from other parts of the world. It may be that the Mediterranean form is well characterized by color. Burton and Rao have implied, but without actual data, that it has similar spiculation to West Indian *Tedania*. On the other hand, published descriptions show that the Mediterranean *Tedania* has the endosomal styles two to seven times as thick as the ectosomal tornotes. I find, in very numerous specimens, no such difference in West Indian *Tedania*, in which the thickness varies from the same to one and one-half times that of the tornotes.

The West Indian form, which I am convinced is specifically distinct from *anhelans*, was first named *Thalysias ignis* by Duchassaing and Michelotti (1864: 83) and transferred to *Tedania* by Verrill (1907: 339). It is regularly brilliant red, almost spectral red, but tending a little toward vermilion. I have examined thousands of specimens, and found extreme uniformity.

Numerous species names for *Tedania* have been established for forms occurring in the East Indian region. These all have spicules thicker than those of *ignis*; they vary from slightly longer to one and one-half times as long. The colors are usually cited as yellow, in a few cases tending toward red.

The allocation of the Hawaiian *Tedania* must be regarded as provisional; I do not feel that its position can be settled at present. If the attitude of Burton and Rao is adopted, it is *Tedania anhelans*, and so are a score of



other forms. In color it is like the East Indian species, unlike typical *Tedania ignis*; but in spiculation it is indistinguishable from *ignis*.

*Tedania ignis* gives a pronounced irritation to most people who touch it (those with very calloused hands are safe). This irritation includes a reddening of the skin, swelling, extreme tenderness to the touch, and lasts 3 to 7 days. I obtained such an irritation from the Hawaiian *Tedania*, and this has influenced me in making my provisional identification.

The correct name of the East Indian species is doubtful too—an additional reason for hesitating to synonymize on the basis of a dubious resemblance. The oldest name that may possibly be available is *Spongia macrodactyla* Lamarck (1814: 458), but its use is beset with difficulties. Its locality is not certainly known; Lamarck himself was not sure, but thought it might be East Indian. Topsent (1933: 13) redescribes Lamarck's material, showing a spiculation like *Tedania*, but he adds that the skeleton is mostly keratose, and his photograph shows a general appearance that might well be that of a keratose sponge. Such forms often contain foreign spicules. If this one had no spiculiferous neighbors except *Tedania*, it might contain only *Tedania* spicules. If the spicules are proper, this is a peculiar *Tedania* because of its large spongin content.

Thiele in 1903 described four species of *Tedania* from the East Indies (Ternate, in the Molucca Sea). These are *reticulata* (p. 946), *coralliophila* (p. 946), *meandrica* (p. 947), and *brevispiculata* (p. 947). The differences in spicule size which Thiele emphasizes are within the range of individual variation and we may be confident that these, all from the one locality, are conspecific, to be known as *Tedania reticulata*. I wish to record at this time, that further studies in the East Indian region may bring about a decision to include the Hawaiian *Tedania* with *reticulata*, rather than with *ignis*. Undoubtedly some authors would designate the Hawaiian form

as a new species and perhaps this may ultimately prove to be necessary.

#### KANEOHEA new genus

This genus is erected in the family Psammascidae with the following species, *Kaneohea poni*, as genotype. It should be emphasized that this is a genus (like all in the family) with a principal skeleton of foreign material, to which are added strongyles, oxeas, styles, and raphides. The genus which is most similar is *Holopsamma*, which has strongyles and styles but not the oxeas and raphides. Oxeas and raphides are each quite unusual in this family.

The generic name is given in honor of Kaneohe Bay.

#### *Kaneohea poni* new species

Fig. 14

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22751. It was collected January 10, 1948, at a depth of 1 meter, growing on dead coral in Kaneohe Bay. Only the one small specimen has so far been found, but it might be sought in the future with some interest.

This specimen is a thin encrustation, about the size and thickness of a shilling or quarter-dollar. The color in life was a brilliant, gaudy purple, one of the most conspicuous color notes one may hope to find. The consistency is mediocre. The surface is smooth, and, as might be expected, the specimen is lipostomous.

There is just the thinnest of fleshy ectosomes, less than  $10\ \mu$  thick, which is very easily destroyed by handling. The endosome is packed with sand grains that are about 30 to  $60\ \mu$  in diameter—so small that they would easily be swept about and carried in water currents. In among these grains there is an isodictyal proper skeleton, with some uniserial spicule tracts.

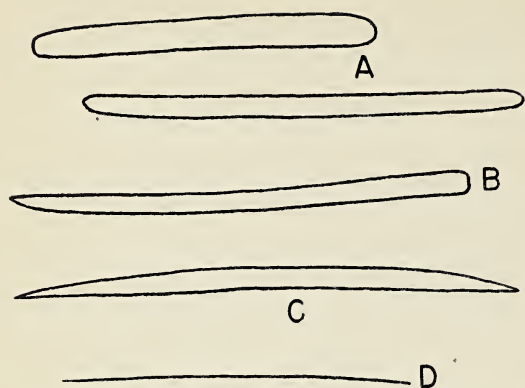


FIG. 14. *Kaneohea poni*, spicules, from a camera lucida drawing,  $\times 666$ . A, strongyles. B, styles. C, oxea. D, raphide.

The spicules show little or no localization, but all three kinds of megascleres make up the reticulation, well mixed. The strongyles are about 5 by 90  $\mu$ , the styles 4 or 5 by 120  $\mu$ , the oxeas also 5 by 120  $\mu$ . The raphides are about 0.5 by 90  $\mu$ .

The species name is derived from the Hawaiian word for purple.

### *Mycale cecilia* de Laubenfels

#### Fig. 15

This species is very common in Hawaii, widely scattered in shallow water locations. Its greatest abundance, however, seems to be in Honolulu Harbor and in Pearl Harbor. The first specimen that I found in Kaneohe Bay was at Moku O Loe, November 3, 1947; this is deposited in the U. S. National Museum, Register Number 22747. It occurred as a large encrustation on a mangrove shoot at location 2 in Figure 2. By December 22, 1947, the whole sponge had disappeared, although I had carefully left most of it *in situ*, and the location was one that would be most easily kept track of and found again. Nor have I been able to find it in that vicinity since. This may have some connection with a reproductive cycle.

This species is encrusting, often about 0.5 to 1 cm. thick. The above mentioned Moku

O Loe specimen covered a mangrove shoot that was some 40 cm. long. The multitude of colors of this species requires further discussion below. The consistency is softly spongy.

The surface is fairly smooth, with many minute, contractile pores. The oscules are about 200  $\mu$  in diameter, but they too are difficult to measure because of their contractility and small size at greatest opening.

The ectosome is a definite dermis over extensive subdermal cavities. The endosome is a reticulation of spicular tracts 30 to 120  $\mu$  in diameter, often about 65  $\mu$  in diameter. Each is packed with spicules, and may possibly, but not certainly, contain spongin. Distally, each ends in a tuft or brush. There are astonishingly few interstitial megascleres.

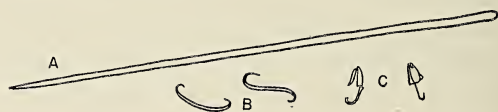


FIG. 15. *Mycale cecilia*, spicules, from a camera lucida drawing,  $\times 333$ . A, style. B, sigmas. C, palmate anisochelas.

The megascleres are tylostyles with long rather than wide heads; their sizes are 4 by 250 to 6 by 240  $\mu$ . The microscleres include commonplace sigmas 30 to 42  $\mu$  in chord length, and palmate anisochelas. These latter are very narrow, so that in boiled-out spicule preparations all lie on their sides. Profile views are thus common but what one may call "face views" are rare and difficult to find. In most specimens these spicules are only 15  $\mu$  long, but in some specimens they range to at least 24  $\mu$ . I found none in rosettes.

There are close to a hundred species names left in *Mycale*, even after the partitioning of the genus undertaken previously (de Laubenfels, 1936: 118). Only about 25 of these, however, have tylostyles rather than the usual styles as megascleres. The additional factor of very narrow anisochelas reduces the number still further.



Duchassaing and Michelotti (1864: 89) described *Pandaros angulosa*, and de Laubenfels (1936: 116) shows that it is a *Mycale*. This is a common West Indian species, and its spiculation is practically identical with that of the specimens which are now under consideration. It is, however, one of the fairly numerous species of *Mycale* that have the following distinctive characteristics: they are extremely coarse with gross chambers upwards of a centimeter in diameter; the flesh and skeleton are largely restricted to the trabeculate partitions. Upon handling a specimen, there is copious production of colloidal slime. I have observed a head-size specimen literally fill a tub with its exudate within 12 hours. *Mycale angulosa* itself has a pronounced tendency to assume a hollow or vasiform habitus.

In a study of the sponges of Panama, de Laubenfels (1936: 447) reported from the Pacific side, at Panama City, intertidal, the new species *cecilia*. This has a spiculation like that of *angulosa* and like our Hawaiian *Mycale*, but this species is encrusting, fine-grained, with few or no gross cavities even as much as 1 mm. in diameter, and scarcely a bit of colloidal exudate upon handling. But for the spicules, one would not consider *cecilia* and *angulosa* to be even in the same family.

The identification of the *Mycale* from Hawaii is complicated by the peculiar color situation. The Panama specimens of *cecilia* were all green, one of the few colors never shown by the Hawaiian specimens. Furthermore, in July and August, 1933 (when I studied it in the field), it was thickly beset with bright red embryos about 200  $\mu$  in diameter. These showed plainly in a specimen held 2 meters away—a bright green but red-speckled and thus curiously conspicuous sponge. In contrast, the Kaneohe specimen above described was a mottled patchwork of pink and lavender. In November, 1947, it was loaded with yellow embryos, 600  $\mu$  in diameter, and these did not show at all from

the surface, but were all in a layer at the base of the sponge and adjacent to the mangrove tissue upon which it was growing. May not such differences in size and color of embryo and color of adult tissue indicate specific difference? Yet this is further complicated by the finding in October and also in March of yellow to orange colored specimens devoid of embryos.

Just as a surmise, a hypothesis to be checked by later field observation, one may wonder if the young embryos are red, changing to orange and then yellow as they enlarge, and if perhaps the young sponge is yellow, then pale orange, then pink, and at last lavender just when reproducing. It may die after giving off a large number of embryos, at an age between 1 and 2 years. This is not groundless surmise, as it is also partially confirmed by some observations of mine upon related species at Bermuda. The green color found at Panama might well be due to the presence of algal symbionts.

#### *Zygomycale parishii* (Bowerbank) Topsent

Fig. 16

This species was first collected from Kaneohe Bay at Moku O Loe, on the shore of the harbor, north of location 6 (Fig. 2) at a depth of 2 meters. This specimen is deposited in the U. S. National Museum, Register Number 22735. It is one of the commonest species at Moku O Loe, but rare or absent elsewhere in Kaneohe Bay. It is extremely abundant as a growth on vessels that remain for a year or so at harbor on the lee side of Oahu, as revealed by study of ship bottoms in the dry-docks at Pearl Harbor.

This is a somewhat ramose sponge; there is an amorphous basal mass from which long processes arise. These processes are extremely irregular in cross section and in long section, too. This is another species of many colors. Probably the commonest is a dull reddish or brownish-purple. Individual specimens are

often polychrome, gradually shading into different hues here and there without apparent relationship to ecological factors or anything else. A few specimens are bluish-violet to gray. The first collected was definitely orange. I found no green, yellow, black, white, or any brilliantly colored specimens of this sponge. One might say that the color ranged from dull orange through mahogany-brown to dull lavender. The consistency is spongy. If any considerable quantity is available, say a good handful, one may discover that this species has a definite odor. I have never found a similar fragrance in any other sponge, nor failed to find it in *Zygomyscale*—some half a dozen times that a large quantity was at hand. This odor is strongly reminiscent of linseed oil, also faintly suggestive of fresh-cut grass, not like phosgene, but much more like old, oxidizing linseed oil.

The surface of this species is rather smooth but not level, and has a very characteristic speckled or punctiform appearance by which one soon comes to recognize it. This is due to a dermal network of fibers. The latter are minute, only about 5 to 10  $\mu$  thick, and the meshes are 65 to 100  $\mu$  in size. However, even when the unaided eye cannot resolve the individual pores or fibers, the over-all appearance can be recognized. The oscules are about 2 or 3 mm. in diameter, often provided with thin, raised rims. They are uncommon and rather difficult to find among obviously accidental surface openings.

The ectosome is a definite dermis over extremely widespread, nearly omnipresent subdermal spaces which may be as much as 0.5 mm. high. It contains the special network already mentioned. The endosome contains a coarser, but still rather fine-grained, network of fibers; these fibers are upwards of 50  $\mu$  in diameter and contain about 15 spicules per transverse section. At their distal terminations they splay out into dermal brushes or tufts.

The megascleres of *Zygomyscale* are of one

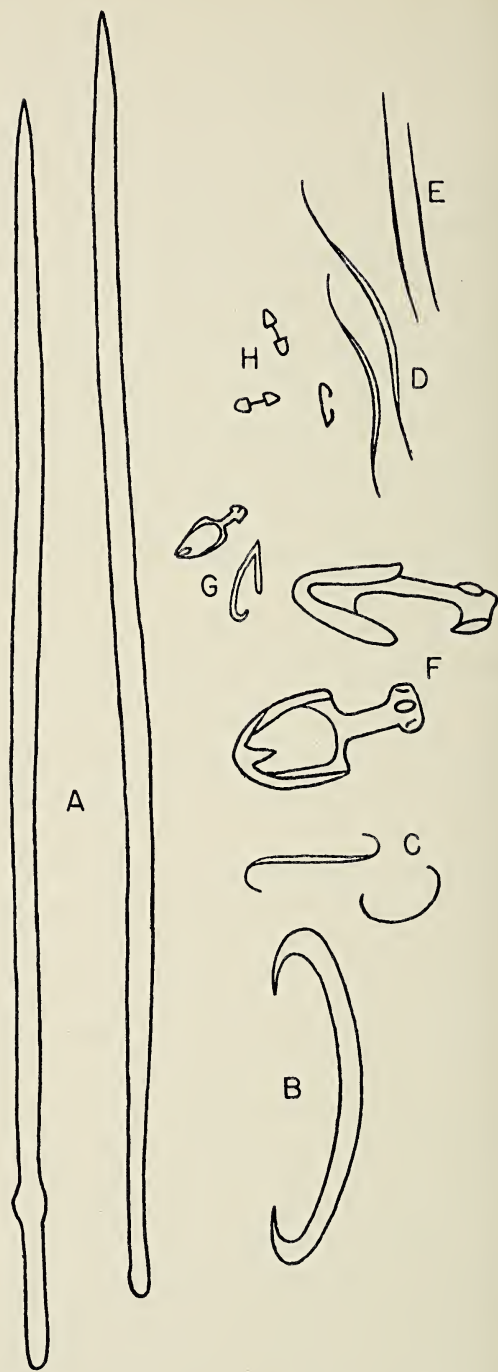


FIG. 16. *Zygomyscale parishii*, spicules, from a camera lucida drawing,  $\times 666$ . A, styles. B, larger sigma. C, smaller sigmas. D, toxas. E, raphides. F, larger palmate anisochelas. G, smaller palmate anisochelas. H, palmate isochelas.



kind only, a subtylostyle with such a vague neck constriction that it is barely perceptible; therefore they often give a first impression of being styles. The microscleres are extremely diversified. Only the genus *Acanthus* can match this one for diversity of small spicules. There are large palmate anisochelas, 40 to (more usually) 48  $\mu$  long, and often grouped in rosettes, small ends together in the center of a spherical arrangement of the larger ends. There are medium-sized palmate anisochelas, 18 to 20  $\mu$  long. There are minute palmate isochelas only 10  $\mu$  long. There are two sizes of sigmas—the larger, 5  $\mu$  in diameter and from 75 to as much as 90  $\mu$  in chord length; the smaller, 25 to 30  $\mu$  in chord length, and only 1 or 2  $\mu$  thick like most sigmas. There are toxas 30  $\mu$  long, and, rarely, also raphides barely 10 to 15  $\mu$  long. They may be more common than first appears, but often overlooked because of their minute size—they are hardly as much as 1 light-wave in diameter.

The genus *Zygomycale* was established by Topsent (1930: 431). The genotype is here designated as the sponge which was first described as *Raphiodesma parishii* by Bowerbank (1875: 283), the name here selected with some misgivings for the Hawaiian *Zygomycale*. Topsent transferred three other species names to his new genus, but two additional ones still require such transfer. They are the species first described as *Esperella ridleyi* by Lendenfeld (1888: 211) and that described as *Esperella crassissima* by Dendy (1905: 160). The original description of *parishii* by Bowerbank is utterly inadequate, and its use here rests entirely upon this circumstance. Burton and Rao (1932: 328) state that it is their opinion that *parishii* and several others now in *Zygomycale* are all conspecific. It is probable that Bowerbank's specimen of *parishii* is in the British Museum; therefore it is probable that Dr. Burton examined it. It is further probable that he really did find it to be conspecific with the

others because of his treatment thereof, above mentioned. If so, *Zygomycale* is monospecific. All the records have been from the eastern part of the Indian Ocean, the East Indies, and Australia; therefore the possibility of conspecificity is great. Thus there may be a link between the East Indian fauna and that of Hawaii, evidenced by the occurrence here of *Zygomycale parishii*.

#### *Hymeniacion chloris* new species

Fig. 17

The holotype of this species is here designated as spirit-preserved specimen, U. S. National Museum, Register Number 22738. It was collected September 11, 1947, at Moku O Loe, from a depth of 1 meter (location number 1, Fig. 2). It is fairly common at that one locality but has not been found anywhere else as yet.

This species forms masses ranging from the size of a hen's egg to that of a small fist. Numerous tapering projections 1 to 2 cm. high and 6 to 14 mm. thick occur. The color is a medium dark green; the consistency is soft, somewhat spongy, but also rather fragile.

The surface is minutely tuberculate. The oscules are 1 to 2 mm. in diameter, usually at the summit of one of the above-described processes, and are readily closed by the sponge within less than 5 minutes after removal from the water. The pores are even more rapidly closed. They are often in groups of 8 to 12, separated by only very thin strands; these groups are about 200  $\mu$  in total diameter.

The ectosome is fleshy, contractile, a true dermis, perhaps 15  $\mu$  thick. The endosome is rather dense, and is packed with spicules. The latter are sometimes loosely organized into strands; more have their points toward

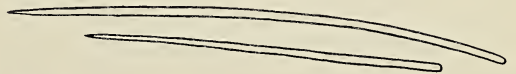


FIG. 17. *Hymeniacion chloris*, spicules (styles), from a camera lucida drawing,  $\times 296$ .

the surface than any other orientation, but many are strewn in confusion.

The spicules are exclusively styles, chiefly 5 by 300 to 7 by 400  $\mu$  in size. A few that are much smaller may be immature.

One hesitates to erect a new species in a genus that, like this one, has fifty names in it already, especially since these are all so much alike in description. On the other hand, this genus has only a few of those traits to which we look for specific separation; were we to consider others, such as chemical composition, serological reaction, and physiological processes, we might find that there really are more diverse species within it than are now suspected. The emphasis is here laid on the green color. Bowerbank (1874: 191) established the name *Hymeniacion plumiger* for two British specimens that he said were green in preservative; what they were in life is unknown. He may have overlooked micro-scleres; therefore we are not sure that these specimens were even of the genus *Hymeniacion*. Their styles were only 4 by 234  $\mu$ . Since Bowerbank's report, no one seems to have found any further specimens to match his description; therefore *plumiger* is not an important species name, and, except for this dubious record, the color is unique in the group. Except for the color, *chloris* is much like *Hymeniacion heliophila*, which is abundant on the Atlantic coast of North America. It must be realized that green color may be due to contained algal symbionts; even so, that a species should specialize in symbiosis may be a valid criterion.

It appears that there are the following valid species of *Hymeniacion* in the world: a yellow one, *caruncula*, in the Mediterranean and north to England; a deep red one, *sanguinea*, from England on north (some experts would synonymize these, but I found them both at Plymouth, England, and definitely decided they were not conspecific); an orange species, *heliophila*, from the Arctic to the West Indies in the West Atlantic; a yellow

species, *sinapeum*, which is practically undistinguishable from *caruncula*, on the west coast of North America; in the same locality also occurs *ungodon* with a peculiar mahogany colored ectosome. In the West Indies *amphilecta* has a curious brown color and corky consistency. Five species names occur in the Indian Ocean and East Indies; all have extremely thick spicules (20 to 40  $\mu$ ) and may all be conspecific. A yellow species, *fernandezii*, from both coasts of South America, is also close to *caruncula*, but *paucispiculus* from Argentina is not certainly of this genus; it is a fan with few spicules and those are of two size ranges. Three species names have been used in this group for New Zealand forms; all three are much alike and may be conspecific; minute differences separate them from *caruncula*. Four Antarctic species each have some distinctive peculiarity, such as centro-style spicules, or verrucose surface. Many other named species are unrecognizable or are already known to fall in synonymy. Assuming *chloris* to be a good species, I opine that there are 14 valid species in the genus.

The species name *chloris* refers to the green color of this sponge.

#### *Terpios zeteki* (de Laubenfels)

Fig. 18

This species is one of the two or three most abundant sponges in Hawaii. My first specimen from this region was collected September 10, 1947, at Moku O Loe at a depth of 1 meter, near the pier (location number 6, Fig. 2). This one is deposited in the U. S. National Museum, Register Number 22739.

This species is sub-ramose. There is a basal mass from which rounded projections arise, often scarcely more than hemispherical, at other places digitate. These projections are usually between 1 and 2 cm. in diameter, from 0 to 5 cm. long. Some masses reach head size. The interior of *zeteki* is consistently an ochre-yellow, but the exterior is con-



trastingly colored. In the type of the genus, *fugax*, the yellow shows over more or less of the surface, the rest being a dark prussian blue. In *zeteki* the yellow never shows and the whole exterior is of one uniform color. This color in nearly 50 per cent of all specimens is a turquoise or robin's-egg blue, in as many other specimens it is rosy-red. This was the color of the above-mentioned U. S. National Museum specimen. After a long search, out of scores of specimens, I began finding an occasional one that was violet—clearly a hybrid of the other two colors. I never found a parti-colored colony but always the entire sponge of the same hue. The consistency is spongy.

The surface of *Terpios zeteki* is tuberculate, almost like the skin condition called "goose pimples." The elevations are less than 1 mm. high and about 3 or 4 mm. apart. The pores are extremely contractile, and so are the oscules, but in life the latter certainly open to as much as 2 mm. in diameter. Their closure is by a sphinctrate contraction involving rather typical muscle cells instead of by the pulling of a membrane across the opening as in some sponges. This muscular closing is quite typical, however, of the order Hadromerina, in which this genus belongs.

The ectosome of this species is very thin, not the usual thick cortex of this order; in fact, it is usually less than  $50\ \mu$  thick, and chiefly organic. The endosome is so densely organic as to resemble cheese; the gross chambers carry out the similarity. There is no segregation of spicule sorts nor any conspicuous tracts. Most of the spicules are in confusion but more have their points toward the surface than with any other one orientation. There are vague ascending tracts, and these end in relatively large, very definite dermal tufts or brushes; in these tufts the spicules bristle, all the points being directed toward the surface or slightly divergent.

The spicules are exclusively tylostyles, of great variation in size. Many are about 4 by

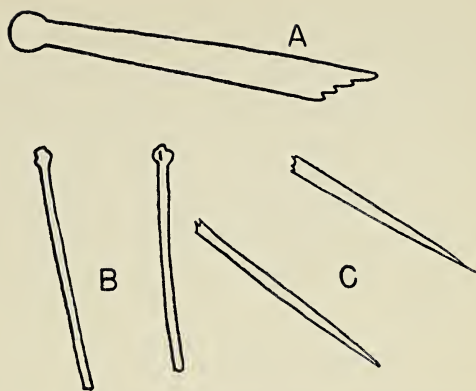


FIG. 13. *Terpios zeteki*, spicules, from a camera lucida drawing,  $\times 666$ . A, the head of one of the common spicules, which are tylostyles. The pointed end, not shown, is commonplace. B, heads of some smaller (juvenile?) tylostyles, which show the hexactinellid pattern. C, pointed ends of the spicules shown at "B"; the mid-regions of them are not shown.

$300\ \mu$ , but 14 by 700 may be expected; many are only 2 (or less) by  $200\ \mu$ . An interesting shape is often found in the slender, unfinished spicules of this species, especially if the whole colony be small and evidently young. In such spicules it can be seen that the head is not just one single swelling, but is due to the existence of four short arms at right angles to each other and to the rhabd or shaft. Such a spicule could be called an orthotetraene; in the *Hyalospongiae* it is called a pentact. These four arms in *Terpios* do not continue to grow; they stop when only about  $1\ \mu$  long and are then buried by successive layers of the opaline silica. When the mass of the head reaches a diameter of about 4 or  $5\ \mu$ , the arms are so thoroughly covered that they can no longer be observed. The genus *Terpios* was based upon the occurrence of these pentactinal spicules; the larger, older specimens were put in a later genus *Laxosuberites*. In a manuscript on the sponge fauna of Bermuda I show the synonymy of the two, and review the genus *Terpios*; that manuscript may be published before this one.

The present species was first described as *Laxosuberites zeteki* by de Laubenfels (1936:

450) from the vicinity of the Panama Canal, especially the Pacific end. The amazing color situation was evident there, half of all the specimens being red, the remaining ones blue-green. In Panama I found no intermediates. Dickinson (1943: 37) records the species from the Pacific coast of Mexico. This species and *Mycale cecilia* afford links between the Hawaiian fauna and that of the tropical Americas.

### *Cliona vastifica* Hancock

Fig. 19

This species was first studied in Hawaii on September 27, 1947, in Waialua Bay (north-west of Kaneohe Bay), at a depth of about 3 meters. This specimen is deposited in the U. S. National Museum, Register Number 22743. The species is common throughout the shallow waters of Hawaii, but is always inconspicuous. If one breaks up almost any long-submerged calcareous material, such as shells or dead coral, one will find this boring sponge. It is very common throughout Kaneohe Bay.

*Cliona vastifica* excavates galleries in calcium carbonate. These are roughly circular in cross section and about 1 mm. in diameter. Each gallery meanders rather than extends in a straight line, and may reach a total length of 5 to 10 cm. Old coral may be so riddled by *Cliona* that it crumbles as one handles it, but this is not common experience in Kaneohe Bay, where usually a crowbar or hammer is required to break up the coral. The sponge is orange in color, and of mediocre consistency. The pores and oscules are minute, and are located at the small inconspicuous openings to the galleries (1 mm. in diameter). Obviously one can say little about ectosome as compared to endosome as long as the sponge lives thus buried. *Cliona* specimens may grow out of their burrows into plain view, but I have not yet found any such in Hawaii. The principal skeleton of *Cliona vastifica* consists of tylostyles 4 by 300 to 7

by 240  $\mu$  in size. Fairly numerous microspined oxeas, 4 by 85 to 5 by 75  $\mu$ , are also present. There are distinctive microscleres, heavily microspined and probably to be regarded as microstrongyles, but the ends are cut off so sharply that they are more like little cylinders. Some are as small as 2 by 8  $\mu$ , others as large as 3 by 18  $\mu$ , with 10  $\mu$  as a common length.

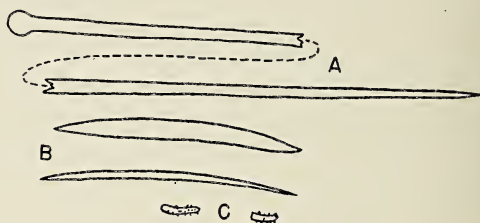


FIG. 19. *Cliona vastifica*, spicules, from a camera lucida drawing,  $\times 444$ . A, tylostyles. B, oxeas. C, microacanthostrongyles.

This species was first described by Hancock (1849: 342) from Great Britain. It is an abundant species throughout the Old World, but quite uncommon (although present) in the New World. In the Americas the boring sponges are nearly always *Cliona celata*; this species is also common in the Old World, but from Norway, to Turkey, to Ceylon, to New Zealand, *vastifica* is a close rival to *celata*. Is *vastifica* perhaps a recent immigrant to North America, carried by barnacles on ship bottoms? Did it reach Hawaii in that same way too?

### *Tethya diploderma* Schmidt

Fig. 20

This species is very common throughout the shallow waters of Hawaii, including Kaneohe Bay. It is represented by some specimens collected November 22, 1947, at Moku O Loe, at a depth of 1 meter, in the long lagoon (location number 3, Fig. 2). These are deposited in the U. S. National Museum, Register Number 22751.

This species is nearly spherical in shape and may become as large as a hen's egg; more



often it is about half this size. The interior is regularly ochre-yellow. The exterior is extremely pale, almost white for specimens that grow in the shade, but a mahogany-brown for specimens which grow in relatively bright illumination. This was true of most of the Moku O Loe specimens. Among the brown tethyas, however, were a few that in life appeared black. In alcohol these promptly bleached to about the brown color that the others had in life, but the brown ones in alcohol bleached very pale indeed. The black specimens had identical spiculation, and in all respects, save for color, appeared to be identical with the brown ones. No difference in their ecological placement could be found to account for the difference in hue. The hypothesis here favored is that the black ones had a symbiont of some sort in or on their dermis, which symbiont was lacking from the brown tethyas. The consistency of this sponge is cartilaginous.

The surface of *Tethya* changes with the reproductive cycle, but is always more or less verrucose. The protrusions are at the distal terminations of spicular fascicles, and are about 2 mm. in diameter. Their height varies during the reproductive cycle from nearly 0 to more than 3 mm. so that they may actually depart from the parent as slowly motile buds. The pores and oscules are very contractile but the latter may open to as much as 2 mm. in diameter. There is seldom more than one oscule per sponge, and it is usually apical.

Schmidt's name *diploclerma* is well deserved by the remarkable ectosome of this sponge. The outer cortex is about 650  $\mu$  thick, and may contain symbionts, reproductive tissue, and protective tissue including microscleres. The inner cortex is about as thick or a little thicker, is pale, full of strong smooth muscle tissue, and very contractile. Not only may the pores and oscules be closed promptly, but the whole sponge seems to grow smaller when these muscle fibers contract.

The endosome is rather dense, and is permeated by radiating columns or tracts of megascleres; each tract is about 200  $\mu$  in diameter. There is one column for each dermal protrusion.

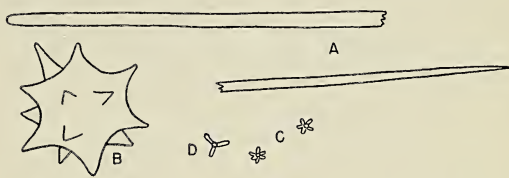


FIG. 20. *Tethya diploclerma*, spicules, from a camera lucida drawing,  $\times 333$ . A, style or fusiform strongyle. B, spheraster. C, small tylasters, common shape. D, euaster, less common shape.

The megascleres are inequidended, fusiform strongyles. The small end is usually pointed toward the surface of the sponge and is so small that the spicule almost becomes a style. Indeed, some actually appear to be genuine styles. They range in size from 8 by 500  $\mu$  up to at least 20 by 1500 and 25 by 1250  $\mu$ . There are two sorts of microscleres. First, there are large spherasters, 25 to 75  $\mu$  in diameter, more often near the larger size. These are chiefly localized just under the cortex. Second, there are myriads of small tylasters with microspined rays. The total diameter of the asters is only 5 to 11  $\mu$ . They are abundant both in the outer cortex and throughout the endosome.

This species was first described by Schmidt (1870: 52) from the West Indies, but has since been shown, especially by Burton (1924: 1039), to be practically cosmopolitan. A very interesting article by Edmondson (1946: 271 and following) discusses the asexual reproduction of this species as it occurs in Hawaii, but uses the name *Donatia deformis*. The name *Donatia* is a later synonym for *Tethya* but was used for a while on the unwarranted assumption that the still earlier name *Tethys* (for a mollusk) preoccupied Lamarck's (1814: 69) establishment of *Tethya*. The two names are, of course, quite different. The species *deformis*

is much like *diploderma* but less elaborate as to dermis, and its micrasters each have a centrum. It is a western Pacific species, from Japan through the East Indies to New Zealand. The species *diploderma* is circum-equatorial. If the two should be determined to be conspecific, as is possible, the name *diploderma* has a 28-year priority.

#### ZAPLETHEA new genus

This genus is erected with the following species, *Zaplethea digonoxea*, as genotype. It is placed provisionally in the family Halinidae, subfamily Corticiinae. It should be emphasized that this is a genus of sponges with extremely abundant microscleres, but very few megascleres, those that are present being oxeads. The microscleres are of two sorts, euasters and twice-bent microxeas.

Twice-bent spicules are exceedingly rare in the phylum Porifera. There is at least one other case, however. This is the record by de Laubenfels (1930: 26; or better, 1932: 35) of *Penares cortius*, a sponge with two kinds of microscleres: euasters and twice-bent microstrongyles. It had a few oxead megascleres, so that if the twice-bent spicules were oxead, there would be agreement to this extent. However *Penares* has a principal spiculation of large tetraxons; thus it goes in the order Choristida. *Penares cortius*, from California, was a large sponge with a conspicuous leathery dermis, very different in appearance from *Zaplethea digonoxea*.

In the order Choristida there is a family Jaspidae. Its type genus, *Jaspis*, has a spiculation of oxeads and euasters, but no twice-bent microscleres; the oxeads are the principal spicules, and are radiately arranged. These are large, significant differences from *Zaplethea*.

The order Carnosa is established especially to receive sponges that have few or no megascleres, and has even been called "Microsclerophora." Thus it seems clearly to be the best order to receive the genus *Zaplethea*.

Yet the family situation in this order is still perplexing; there are now four families in the Carnosa, and none quite fits *Zaplethea*.

The Chondrosiidae have no spicules at all.

The Chondrillidae have only euasters.

The Plakinastrellidae have a few megascleres, as no others in the order do, and thus are intermediate. But the megascleres that are present are tetraxons, so that the intermediate condition obtains as between the Carnosa and the Choristida. For lack of tetraxons, *Zaplethea* seems utterly out of place in the Plakinastrellidae.

The fourth family is the Halinidae, here selected by elimination. Yet all the genera of this family (there are about a dozen) have a peculiar microscle known as calthrops. Other than this, these genera are divided into two subfamilies; the Halininae have asters that are streptasters, while the Corticiinae have asters that are euasters.

If we focus attention on the above-mentioned fact that every other genus in this family has calthrops, and regard this as a reason for excluding *Zaplethea*, we are thrown into the embarrassing situation of needing a new family to receive this genus. I do not want to erect any more families in the Porifera, because I believe there is a large enough number already.

The genus name is derived from the Greek "zaplethes," meaning very full, because the sponge is so packed with spicules. The exact Greek is not available, having been used in 1868 in Hymenoptera, also in 1920 in Pisces.

#### *Zaplethea digonoxea* new species

Fig. 21

The holotype of this species is designated as spirit-preserved specimen, U. S. National Museum, Register Number 22746. It was collected September 27, 1947, in Waialua Bay, at a depth of between 4 and 8 meters, growing on dead coral. A second specimen was collected in Kaneohe Bay on January 10,



1948, at a depth of 2 meters, also on dead coral.

This species is encrusting, about 3 to 5 mm. thick. The color is pale, dull, and may be termed drab, or yellowish-gray. The consistency is firm, somewhat like cartilage. The surface is smooth and lipostomous. There is no sharply defined cortical region. The interior is exceedingly dense, with few cavities larger than  $40\ \mu$  in diameter. The flagellate chambers are about  $25\ \mu$  in diameter.

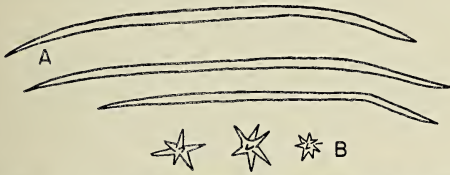


FIG. 21. *Zaplethea digonoxea*, spicules, from a camera lucida drawing,  $\times 444$ . A, microxeas. B, euasters. The larger oxeas are not shown.

There are a few scattered oxeas, 7 by 400 to 12 by 520  $\mu$  in size. They are so rare that while I had only the one specimen I considered them accidental, foreign inclusions. But they were not only present in the second specimen, they were a little more nearly common in it. The whole sponge is densely packed with millions of microscleres. They are of two sorts, about equally abundant. One kind is an oxyeuaster, usually  $10\ \mu$ , but ranging on up to  $20\ \mu$ , in diameter. The other very distinctive kind is a twice-bent microxea. The three straight regions make obtuse angles and are not quite equal in length; instead the middle piece is a little longer than the others. The over-all length is about  $105\ \mu$  and the thickness  $3\ \mu$  or less.

The species name stresses the twice-bent microxea; in fact, this novel sort of spicule itself may suitably be named digonoxea.

### *Plakortis simplex* Schulze

Fig. 22

This species was found in Hawaii on January 10, 1948, in Kaneohe Bay, at a depth of about 2 meters, growing on dead coral. An-

other specimen was found on May 15, 1948, at Keaukaha near Hilo on the island of Hawaii, just below low tide mark.

This is a thin, encrusting sponge, seldom much more than 2 mm. thick. The two specimens covered about 10 square cm. each. The first was dull olive-brown, the second dull gray—this species is usually brown, but dull or drab. The consistency is rather like that of cheese.

The surface is smooth but not level, being often elevated into low tubercles. As usual in such thin sponges, it is lipostomous. There is a paper-thin fleshy dermis; the rest of the sponge is also very dense. It is astonishingly full of flagellate chambers which are round and are 30 to  $40\ \mu$  in diameter. The spicules are crowded throughout the flesh in confusion. Much of the skeleton is merely the usual interstitial jelly.

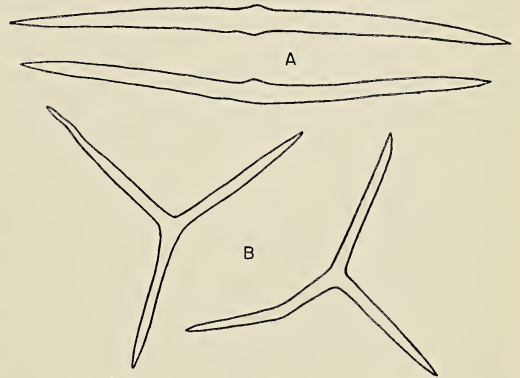


FIG. 22. *Plakortis simplex*, spicules, from a camera lucida drawing,  $\times 380$ . A, oxeas (?). B, triaxons.

The spicules of *Plakortis* are chiefly to be regarded as triacts, and about one in twenty is indeed a neat, symmetrical triact as in calcareous sponges. The rays are often about 5 to 7 by  $100\ \mu$ . More common are spicules that show signs of being a triact with one ray missing, so that the result is V-shaped. Very much the commonest of all are spicules that seem at a casual glance to be oxeas, but which have a central swelling or series of

kinks, so that they are probably triacts with one ray lost and the other two brought into nearly the same line.

This species was first discovered by Schulze in the Mediterranean (1880: 430). Someone (Dendy, I believe) found it again in an East Indian collection. I have found it in the West Indies (Tortugas) and in Bermuda, and now in two places here. It is probable that it is not so rare as it is simply overlooked because of being dull, drab, and thin; one might say it is camouflaged on the rocks that it normally inhabits.

*Leucetta solida* (Schmidt) Dendy and Row  
Fig. 23

In Kaneohe Bay in particular, and throughout the Hawaiian Archipelago in general, small fragmentary calcareous sponges are very commonly found, usually growing on dead coral in shallow water, but also down to at least 50 meters depth (in my experience). These fragments are chiefly of a species that is clearly a *Leucetta*. A few calcareous sponges that are of other genera have been found in the Archipelago, but not yet in Kaneohe Bay.

The genus *Leucetta* is outstanding in the class Calcispongiae for its morphological resemblance to those sponges that are typical of the class Demospongiae. Most calcareous sponges have symmetrical, cylindrical shapes, with large central cloacal hollows, so that they are somewhat like the sponges of the class Hyalospongiae. It is common to find *Leucetta* species that are taken for Demospongiae until the acid test is applied to the (calcareous) spicules.

The genus *Leucetta* is cosmopolitan, especially common in the Antarctic and also in equatorial waters around the world. Some 18 species are commonly recognized. Of these, a few are unique; a new genus may indeed be needed for *Leucetta trigona*. Many others are separated by very small differences and may eventually prove to be conspecific.

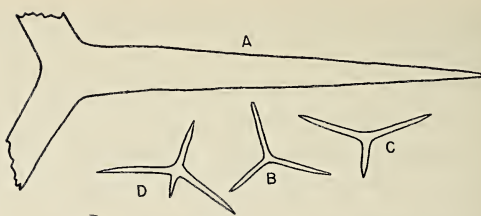


FIG. 23. *Leucetta solida* (?), spicules, from a camera lucida drawing,  $\times 333$ . A, portion of one of the larger triaxons. B, common triaxons of smaller size. C, alate triaxon. D, tetraxon.

I do not yet have material adequate for a proper evaluation of the Hawaiian *Leucetta*, unless it be a specific characteristic that it should always seem to be just a fragment of a sponge. These specimens are usually amorphous, about as large as beans, white, fragile, and full of triaxon spicules of two size ranges. These traits are true of practically all species in the genus. The larger spicules have rays 100 to 120  $\mu$  thick and 660 to 960  $\mu$  long and thus are visible to the unaided eye. The smaller ones have rays 6 to 10  $\mu$  thick and 70 to 110  $\mu$  long. A few intermediates are probably developmental forms of the larger size range. I found one lone tetraxon, of the smaller size range. This may have been an accidental malformation, or an accidental (foreign) inclusion. Again, one must note that many calcispongiae have such spicules in the lining of a cloaca, but not elsewhere. I have not yet found a cloaca in a specimen which is for certain one that occurs in Kaneohe Bay; however, it may be that a cloaca is part of this sponge's full complement of traits, and will be discovered later. On March 29, 1948, I found a calcisponge on the bottom of a barge in dry dock at Pearl Harbor. It had a cloaca lined with small tetraxons. It may or may not be the *Leucetta* that is locally widespread; more study is required.

Of all the species names available in the genus *Leucetta*, the oldest is *solida*. Schmidt (1862: 18) described *Grantia solida* from the Mediterranean. Dendy and Row (1913:



734) correctly transferred this to *Leucetta*. Schmidt's description is so generalized that many other *Leucetta* species could be put with it, and thus our Hawaiian *Leucetta* may be tentatively identified. It is here left an open question whether or not several later species names should be dropped in synonymy to *solida*.

Needless to say, this Hawaiian calcsponge does not help in determining faunal relationships to others parts of the world.

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# Chromosome Numbers of Some Species of *Passiflora* Occurring in Hawaii<sup>1</sup>

W. B. STOREY<sup>2</sup>

## INTRODUCTION

PASSIFLORA IS A GENUS of approximately 400 species of plants, mostly woody or herbaceous vines. About 360 species are native to tropical and subtropical North and South America and adjacent islands. The remainder are indigenous to southeastern Asia, a number of south Pacific islands, and Madagascar (Killip, 1938: 9). Man has been instrumental in disseminating many of the species with edible fruits or with highly colored, attractive flowers, and representatives of the genus are now to be found in most tropical lands throughout the world.

Several species of *Passiflora* have been introduced into the Hawaiian Islands for cultivation for their edible fruits (Pope, 1935). Additional species have been introduced for growing as garden ornamentals. A number of species, both edible and ornamental, have escaped from cultivation and are now to be found in a naturalized wild state along waysides, on waste lands, and in lower forest regions (Pope, 1929: 149). A total of 22 species has recently been reported as occurring in Hawaii (Neal, 1948: 522-525).

A number of edible species, of which *P. edulis* is the most important, are cultivated as commercial crops in Australia, New Zealand, and South Africa, where extensive use is made of the fruit. Their culture is practiced to a lesser degree in various other tropical countries, and in Florida, California, and

Hawaii. Numerous ornamental species and species-hybrids constitute an important item in the plant nursery business in the United States and elsewhere.

Nurserymen have enjoyed some success in producing interspecific hybrid varieties for the floricultural trade. Fruit breeders, on the other hand, have had little or no success in attempts to improve upon existing edible types through interspecific hybridization, largely because of hybrid sterility.

Cytological studies of plants often serve as a useful adjunct to plant breeding problems. Chromosome numbers and chromosome behavior frequently indicate origins of species and relationships between species, and provide clues as to which species are most likely to be compatible upon crossing. Despite the amount of breeding which has been done among species of *Passiflora*, in Hawaii and elsewhere, the genus is but poorly understood from the standpoint of cytology. The recently published *Chromosome Atlas of Cultivated Plants* lists the chromosome numbers of only seven species (Darlington and Janaki Amal, 1945: 114).

This paper deals principally with reporting the chromosome numbers of additional species of *Passiflora* as well as of a number of botanical varieties and forms, interspecific hybrids, and an intraspecific chromosomal race. Notes on cytological behavior have been added where they might be helpful in clarifying origins or relationships.

## MATERIALS AND METHODS

Chromosome numbers were determined for all species of *Passiflora* of which material for study could be obtained in Hawaii. Counts were made from root tips of seedling plants

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<sup>2</sup>Department of Horticulture, University of Hawaii Agricultural Experiment Station. Manuscript received May 24, 1949.

or rooted cuttings, and, whenever possible, from suitable flowering material. Root tips were stained by the crystal-violet-iodine method following Randolph's (1935) schedule. Anthers from young buds were examined in smear preparations with the use of iron-acetocarmine (Belling, 1926).

The figures were drawn with the aid of a camera lucida.

OBSERVATIONS

All species and subspecific forms for which chromosome numbers have been determined are listed in Table 1. They are placed in the table in the order in which they occur in Killip's (1938) systematic treatment of the genus. Interspecific hybrids which are not included in Killip's treatment are placed at the bottom of the table. The list comprises 16 species, 1 botanical variety, 4 botanical

forms, 4 interspecific hybrids, and a polyploidal race of one species.

Six of the seven species listed in the chromosome atlas of cultivated plants (Darlington and Janaki Ammal, 1945: 114) are reported to occur in Hawaii (Neal, 1948: 522-525). These species are *P. caerulea* L., *P. edulis* Sims., *P. foetida* L., *P. incarnata* L., *P. quadrangularis* L., and *P. racemosa* Brot., all of which are reported to have chromosome numbers of  $2n = 18$ . The seventh species, *P. lutea* L., with a chromosome number given as " $2n = 84?$ ," is not known to be in the islands. Of the 22 species listed by Neal (loc. cit.), the writer was unable to obtain material of the following seven: *P. alata* Dry., *P. coccinea* Aubl., *P. antioquiensis* Karst., *P. kermesina* Link and Otto, *P. racemosa* Brot., *P. Banksii* Benth., *P. fruticosa* Killip.

TABLE 1  
CHROMOSOME NUMBERS OF VARIOUS SPECIES, SUBSPECIFIC FORMS, AND INTERSPECIFIC HYBRIDS OF *Passiflora*

PASSIFLORA SPECIES	CHROMOSOME NUMBER	
	N	2N
<i>P. suberosa</i> L. . . . .	12	24
<i>P. suberosa</i> (triploid) . . . . .	18*	36
<i>P. lutea</i> L. . . . .	----	84?†
<i>P. pulchella</i> HBK. . . . .	6	12
<i>P. mollissima</i> (HBK) Bailey . . . . .	----	18
<i>P. manicata</i> (Juss.) Pers. . . . .	----	18
<i>P. vitifolia</i> HBK. . . . .	9	18
<i>P. quadrangularis</i> L. . . . .	----	18
<i>P. ligularis</i> Juss. . . . .	----	18
<i>P. Seemannii</i> Griseb. . . . .	9	18
<i>P. maliformis</i> L. . . . .	9	18
<i>P. laurifolia</i> L. . . . .	9	18
<i>P. incarnata</i> L. . . . .	----	18
<i>P. edulis</i> Sims. . . . .	9	18
<i>P. edulis</i> form <i>flavicarpa</i> Degener . . . . .	9	18
<i>P. caerulea</i> L. . . . .	9†	18†
<i>P. subpeltata</i> Ortega . . . . .	9	18
<i>P. foetida</i> L. . . . .	10	20‡
<i>P. foetida</i> (3 variant forms) § . . . . .	10	20
<i>P. foetida</i> variety <i>gossypifolia</i> (Desv.) Mast. . . . .	10	20
<i>P. Pfordtii</i> (= <i>alata</i> Dry. × <i>caerulea</i> L.) . . . . .	----	18
<i>P. maliformis</i> L. × <i>laurifolia</i> L. . . . .	----	18
× <i>P. caerulea</i> L. (hybrid) (Degener, 1934) . . . . .	----	18
<i>P. princeps-coccinea</i> (= <i>racemosa</i> Brot. × <i>coccinea</i> Aubl.) . . . . .	9†	18†

\* Some meiotic irregularity.  
 † Reported in *Chromosome Atlas* (Darlington and Janaki Ammal, 1945: 114); not seen by author.  
 ‡ Reported as  $2n = 18$  by Janaki Ammal (Darlington and Janaki Ammal, 1945: 114).  
 § Variety or form names, if any, not determined by writer.



On the basis of somatic chromosome numbers which are reported in Table 1 and of numbers previously reported in the literature, all of the species, hybrids, and varieties investigated to date may be classified into six chromosome number groups. These groups and the species belonging to them are as follows:

$2n = 12$ —*P. pulchella*

$2n = 18$ —*P. mollissima*; *P. manicata*; *P. vitifolia*; *P. quadrangularis*; *P. ligularis*; *P. Seemanni*; *P. maliformis*; *P. laurifolia*; *P. maliformis*  $\times$  *laurifolia*; *P. racemosa*; *P. coccinea*; *P. racemosa*  $\times$  *coccinea*; *P. incarnata*; *P. edulis*; *P. edulis* f. *flavicarpa*; *P. alata*; *P. caerulea*; *P. alata*  $\times$  *caerulea* (*Pfordti*);  $\times$  *P. caerulea*; *P. subpeltata*; (*P. foetida* ?).

$2n = 20$ —*P. foetida*, and 3 variant forms; *P. foetida* var. *gossypifolia*.

$2n = 24$ —*P. suberosa*

$2n = 36$ —*P. suberosa*

$2n = 84?$ —*P. lutea*

The  $2n = 12$  group consists of but a single species, *P. pulchella*.

The  $2n = 18$  group comprises 15 species, 4 interspecific hybrids, and 1 botanical form, with 1 species doubtful. Janaki Ammal (loc. cit.) determined the somatic chromosome number of *P. foetida* to be 18. The writer, on the other hand, has examined considerable material of *P. foetida*, its botanical variety *gossypifolia*, and several variations, all of which occur as common wayside weeds in

Hawaii, and has never failed to find 20 somatic chromosomes (Fig. 1). Examinations of dividing sporocytes have consistently revealed 10 bivalents normally paired (Fig. 2). The writer, therefore, is disposed to place *P. foetida* in a separate group consisting only of itself and its varieties. The possibility is not excluded, however, that the Hawaiian representatives of the species may be aberrant forms. *P. foetida* probably was limited



FIG. 2. Meiotic metaphase I in *P. foetida* showing 10 bivalent chromosomes.

to a single introduction from which all of the plants presently populating the several islands are derived.

Microsporogenesis was observed to proceed along a normal course in all of the species in the  $2n = 18$  group. A single exception was noted in *P. subpeltata*, in which syndiploidy occurred in one locule of an anther. The sporocytes in this locule were seen at diakinesis to have 2 large nucleoli and 18 pairs of associated chromosomes instead of the usual 9 pairs. There seemed to be no strong tendency to form multivalent configurations, and it is supposed that such sporocytes would have proceeded to give rise to diploid microspores. The condition very probably arose through failure of a mitotic anaphase in the meristem from which the sporogenous tissue was derived.

Pope (1935: 11) proposed a hybrid origin for *P. edulis* f. *flavicarpa*, possibly as a cross between *P. edulis* and *P. ligularis*. The supposition is not borne out in studies of cytological behavior, for meiosis is normal in every respect (Fig. 3), and both the ovules and the pollen grains are fully viable. The



FIG. 1. Mitotic metaphase in *P. foetida* root tip showing 20 somatic chromosomes.

chromosome number of 18 shows that the plant is not a double diploid, and, therefore, in view of its full fertility, very probably not an interspecific hybrid. A review of the history of *flavicarpa* points to a more probable origin as a mutation of *P. edulis*. There are several notable differences between typical *edulis* and form *flavicarpa*, however, including a high degree of cross incompatibility. The two forms of the species deserve more study from the standpoints of both cytology and genetics.



FIG. 3. Meiotic metaphase I in *P. edulis* form *flavicarpa* showing 9 bivalent chromosomes.

No flowering material of *P. Pfordti*, *P. maliformis*  $\times$  *laurifolia*,  $\times$  *P. caerulea*, or *P. princeps-coccinea* could be obtained by the writer for studies of chromosome behavior at meiosis in these interspecific hybrids. All four appear to be completely sterile.

*P. suberosa* is the sole representative of the  $2n = 24$  group. Microsporogenesis is normal in the species, but there is evidence of strong



FIG. 4. Meiotic metaphase I in *P. suberosa* showing 12 bivalent chromosomes. Broken lines indicate pairs of bivalents in secondary association.

secondary association between the bivalents at the first metaphase (Fig. 4). Secondary association in meiosis has been regarded as indicative of an earlier polyploidal origin (Darlington 1932: 219-223).

*P. suberosa* is also the sole representative of the  $2n = 36$  group. This 36-membered form is undoubtedly an autotriploid derivative of the 24-membered form, constituting a separate chromosomal race within the species. There are no conspicuous morphological differences between the two forms. The only distinguishable differences are to be found in the slightly larger leaves and a slight intensification of anthocyanin pigmentation in the young stems and on the dorsal surfaces of the sepals of the flowers of the triploid form. The species, however, is highly polymorphic, with all degrees of intergradation among its numerous variants, so that even these differences are not entirely reliable as a means of distinguishing the two races in nature. The triploid race appeared spontaneously among wild populations of the diploid race, the first collection being made in 1937. It produces fertile seeds, and has continued to reproduce and spread under natural conditions. Examinations of all herbarium sheets of collections made prior to 1937 in the Bernice P. Bishop Museum at Honolulu reveal none which might conceivably be the triploid form.

Contrary to what might be expected of an autotriploid, triploid *P. suberosa* goes through microsporogenesis with a fairly high degree of regularity and produces a preponderance of normal quartets of microspores. Megasporogenesis must be equally little disturbed, for the fruit produces a complement of seeds more or less comparable to that produced by the diploid. Multivalent chromosome configurations were observed in a few microsporocytes, indicating that there is some disturbance to normal bivalent pairing. In an occasional sporocyte, all orders of association from univalence to sexivalence have been observed. Anaphasic separation into equal



numbers appears to be effected rather uniformly despite multivalence, however, for daughter nuclei were rarely seen to contain more than, or fewer than, 18 chromosomes. There are extremely few abnormal microspore quartets, and correspondingly few abortive pollen grains.

#### DISCUSSION

Darlington and Janaki Ammal (1945: 114) give  $x = 9$  as the basic chromosome number of the genus *Passiflora*. This number was doubtless assumed on the basis of 6 species with  $2n = 18$  and one species which was reported as " $2n = 84?$ ." Determination of  $n = 6$  for *P. pulchella* indicates that not 9 but a lower number probably is basic in the genus. With the exception of the aberrant species *P. foetida* ( $2n = 20$ ), all of the species examined, including *P. lutea* ( $2n = 84?$ ), comprise a polyploid series of which the monoploid number is 6. It is recognized that the total of 29 species and variant forms for which chromosome numbers are known or presumed is but a meager sample from a genus with over 400 known species, so it seems not unreasonable to suppose that other numbers, both euploid and aneuploid, may exist among species unreported here.

It is perhaps significant from the breeders' standpoint that all of the horticultural forms studied occur in the  $2n = 18$  group. These forms exhibit a fairly high degree of interspecific compatibility, as evidenced by the numerous hybrids recorded (Bailey, 1935: 2487); but the hybrids themselves are almost invariably sterile. Their compatibility suggests closeness in relationship and, possibly, a common origin.

With an assumed basic number of  $x = 6$  for the genus, the species in the  $2n = 18$  group must be regarded as triploids. Triploidy, however, is generally considered to be a hindrance to the origin of fertile species because of the high order of meiotic irregu-

larity which it induces. It seems unlikely, therefore, that the majority of species examined, all of which are fertile, have originated through triploidy. An assumed basic number of  $x = 3$  would afford a number of more nearly reasonable explanations of the origin of  $2n = 18$  species. These species could then be regarded as hexaploids of more or less ancient origin. As has occurred in many polyploid species of plants, cytological evidence of genomic composition has disappeared in the course of speciation and stabilization except in chromosome numbers.

How speciation within a group could occur is illustrated by the mutation from *P. edulis* to the form *flavicarpa*. The nature of the mutation has not been studied, but when it occurred it must have been drastic. The form differs from the species in several foliar and stem characters. The fruit is yellow instead of purple, and the seeds are brown instead of black. In addition, the flowering habit has been modified from strictly diurnal to partly nocturnal, and a barrier of almost complete incompatibility seems to have arisen between the mutant form and the species from which it is presumed to be derived. As mentioned earlier, the hybrid origin which was suspected by Pope (1935: 11) is not borne out by cytological studies.

*P. foetida* ( $2n = 20$ ) and its varieties make up a group divergent from the euploid series to which all other species examined belong. Cytological studies to date have provided no clue to its probable origin. The possibilities exist either that it arose as a secondary polyploid from a  $2n = 18$  species or that it belongs to a second euploid series, perhaps with a monoploid number of 5, for which additional species have yet to be discovered. If the plants growing in Hawaii are truly representative of the species, Janaki Ammal's (loc. cit.) determination of  $2n = 18$  as the chromosome number must be considered to be in error.

As noted earlier, strong secondary association in *P. suberosa* ( $2n = 24$ ) is taken as indicative of its polyploid origin. The 36-membered form undoubtedly originated fairly recently as an autotriploid as shown by the absence of marked morphological differences in plant characters. It is supposed that triploidy resulted in the species through the mating of an unreduced gamete with a normal, reduced gamete. How the unreduced gametes might have been produced is suggested by the case of syndiploidy observed in an anther of *P. subpeltata*.

The occasional occurrence of all degrees of multivalence up to and including sexivalence lends credence to the supposition that the  $2n = 24$  form is itself polyploid, at least tetraploid if not of a higher order of polyploidy, and that the derived form is at least hexaploid. The presence of 6 genomes, although bringing about some slight degree of irregularity in meiosis, allows for more or less normal anaphasic separation into two gametic 18-chromosome complements.

#### CONCLUSION

The study has shown that the basic chromosome number for the genus is at most  $x = 6$ , and may possibly be  $x = 3$ , rather than  $x = 9$  as indicated by Darlington and Janaki Ammal (1945: 114). It has also called attention to the discrepancy in chromosome number determinations for *P. foetida*. It is thought by the writer that the aneuploid number of *P. foetida* presages the existence of another euploid series in the genus. The determinations made bring to 29 the number of species and variant forms for which chromosome numbers are known or may be assumed from the composition of various hybrids.

It seems highly probable that there may exist chromosome numbers other than those reported here among the 300-odd species of *Passiflora* which have not been examined.

Studies of a greater number of species more fully representing the recognized taxonomic groups and of additional interspecific hybrid material would aid considerably in determining origins and relationships within the genus.

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# Observations on the Heart Shell, *Corculum cardissa* (L.), and Its Associated Zooxanthellae

SIRO KAWAGUTI<sup>1</sup>

## INTRODUCTION

THE HEART SHELL, *Corculum cardissa* (L.), has a peculiar type of shell. It is greatly compressed antero-posteriorly, resulting in a distinct heart shape, which is the source of the common name. Moreover, it has many zooxanthellae in its gill filaments, labial palps, mantles, and liver. The peculiar shape and habits of this mollusk may be explained by this association with zooxanthellae.

This is the second case of association with zooxanthellae known in the lamellibranchs. It is interesting to compare it with the other. Tridacnidae, which is fully described by Yonge (Rept. Great Barrier Reef Expedition 1928-1929. 1: 283-321, 1936).

These observations and experiments were carried out at the laboratory of the Palao Tropical Biological Station and the reef flat in its vicinity in 1936 and 1940. A preliminary report was published in 1941 in *Science of the South Sea* (*Kagaku Nanyo*) 3: 179-180 [in Japanese].

## HABITAT

At Palao *Corculum* is found on reef flats under strong sunshine. It usually lies on the sand flat where dead shells and coral fragments have accumulated, and its anterior end faces the ground. It lies in a roughly horizontal position, excavating the bottom to the form of its shell, which is sometimes greatly produced anteriorly, as is shown in Figures 2 and 3. There is usually no attachment to the bottom but exceptionally there are several short threads of byssus.

It is very difficult to find the shell in its habitat, as the upper surface is frequently covered with filamentous algae or muddy depositions. In an active state the shell opens by 2-3 mm. at the ventral end and a vigorous current is produced from an exhalant siphon which is projected slightly at the middle of the shell. An inhalant siphon is situated ventrally and on the same level of the shell. At the ventral end of the shell the mantle is separated. Very thin, small papillae appear at the distal portion.

## THE SHELL

One specimen of shell is seen in Figures 1 and 2, from the top (or posterior in anatomical point of view) and left sides, respectively. The boundary of the shell rests, usually, on a plane but it is frequently slightly convex or concave. The height is not the same from

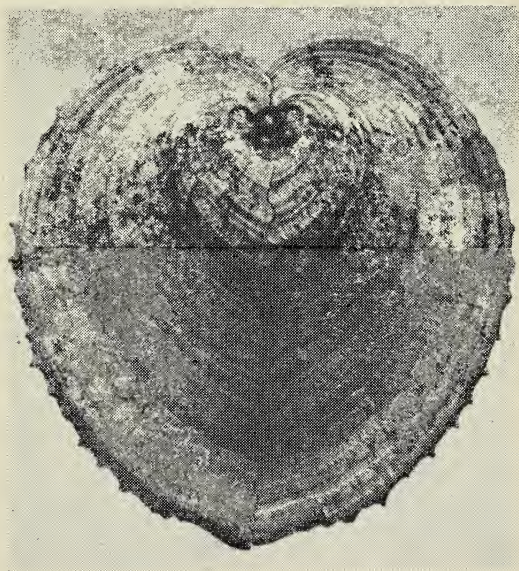


FIG. 1. Upper (posterior) surface of heart shell. (Natural size.)

<sup>1</sup>Department of Biology, Okayama University, Okayama, Japan. Manuscript received January 28, 1949.

the mid-line to the posterior end as it is to the anterior end. The form of the shell is variable as is shown in Figure 3.

Side views of the shells usually display many similarities to those of *Cardium*. In some cases, however, the posterior surface is almost completely flat, with the posterior end of the shell indicated by a little projection and with somewhat of a depression at the mid-portion.

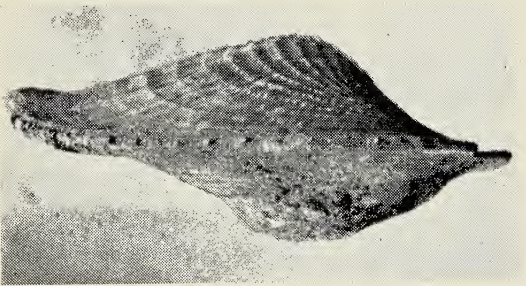


FIG. 2. Lateral view of heart shell. (Slightly reduced.)

It is frequently observed that a smaller shell has a rather elongate shape and a larger one has a more rounded shape. This relation may also be traced in one shell as is shown in Figure 4. When the shell outline is supposed as cut off at a certain growth line the remaining parts of the shell represent the form of the younger shell. In this manner, a series of shell forms is obtained such as is shown in Figure 4 *a-i*. These figures clearly show that the younger form is more elongate than the older one. This relationship is shown numerically in Table 1. The ratio of breadth

(lateral width) to height (dorso-ventral) is greater in the larger specimens.

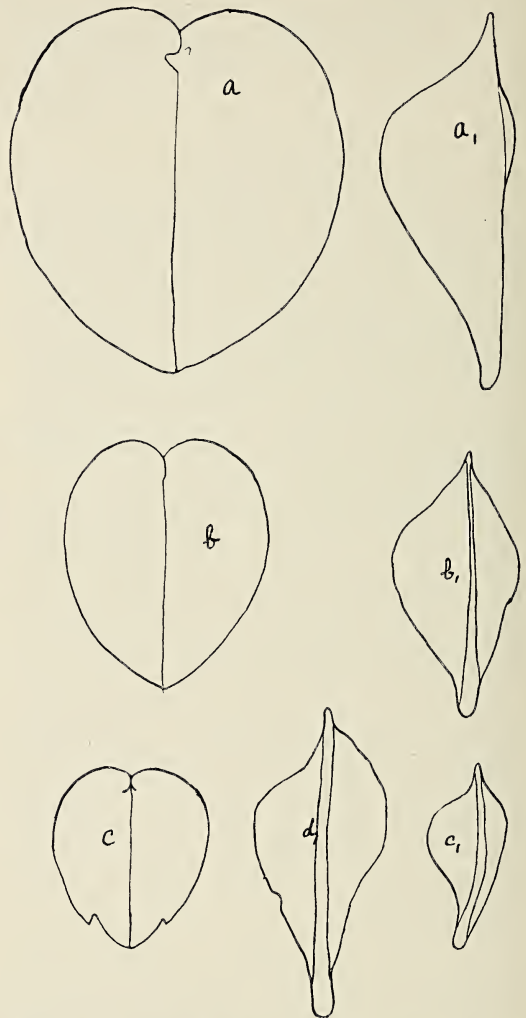


FIG. 3. Outlines of shells of *C. cardissa* showing variations in shape of shell. *a, b, c*, Posterior profile; *a1, b1, c1, d1*, lateral profile.

TABLE 1  
MEASUREMENTS OF THE SHELL OF *Corculum cardissa*

LOCALITY	HEIGHT	BREADTH	LENGTH	THICKNESS	TOTAL WEIGHT	B/H*	S†	W/S‡
	cm.	cm.	cm.	mm.	gm.			
Palao . . . .	6.50	6.00	2.50	0.5-0.7	13.4	0.92	61.7	0.217
Palao . . . .	5.63	5.20	2.36	0.5-0.6	8.7	0.92	42	0.207
Ryukyu . . . .	4.66	3.87	2.4	0.5	6.5	0.83	24	0.270
Ryukyu . . . .	3.25	2.85	1.45	0.2-0.3	1.99	0.88	14	0.14

\* B/H Ratio of breadth to height.  
† S Surface area in square centimeters.  
‡ W/S Weight in grams per square centimeter of surface area.



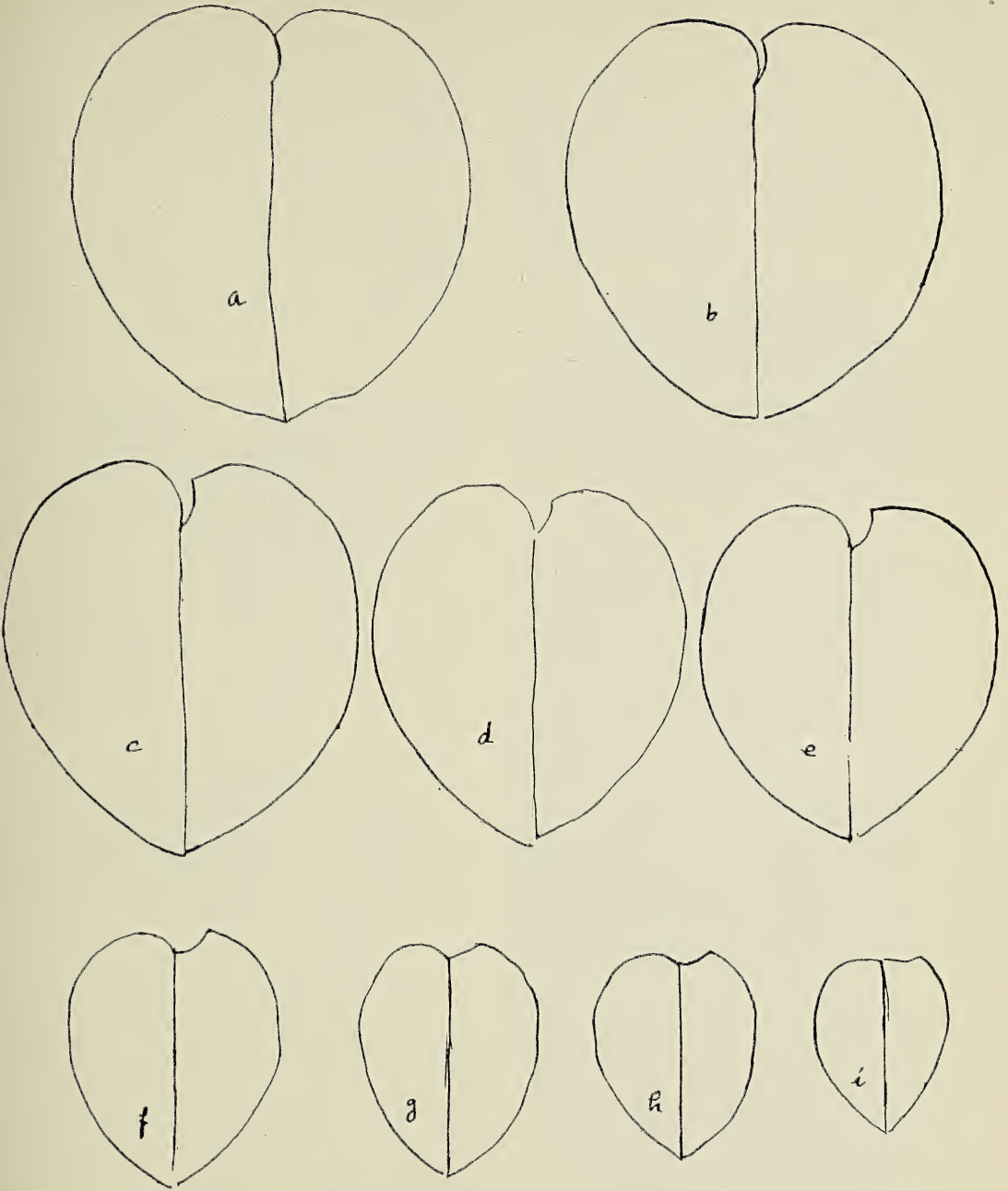


FIG. 4. Reconstruction of a series of growth forms of *C. cardissa*. (Explanation in text.)

The shell is remarkably thin, as is shown in Table 1. It is also remarkable in the uniformity of the thickness throughout the whole shell. Only at the anterior, that is, lower, side the ventral portion shows a slight thicken-

ing. In a very small specimen the shell is very thin but it rapidly attains a maximum thickness of between 0.5 and 0.7 mm. The area of cross section of shell is measured and weight of shell per unit of this area is cal-

culated in column 9. These data also bear out the same fact.

In a first glance at the shell, the lower side seems to be thicker than the upper side. But actually they are almost of the same thickness. This apparent difference is a result of the greater transparency of the upper side. On this side, there is a beautiful pattern which is shown in Figure 5. The pattern is formed by the mosaic arrangement of transparent mass and nontransparent whitish mass. On the lower side the transparent portions are scattered, rarely in rather large masses, and fade into whitish ground. Transparency of the shell is intensified if the shell is immersed in water because of elimination of reflected light from the uneven surface.

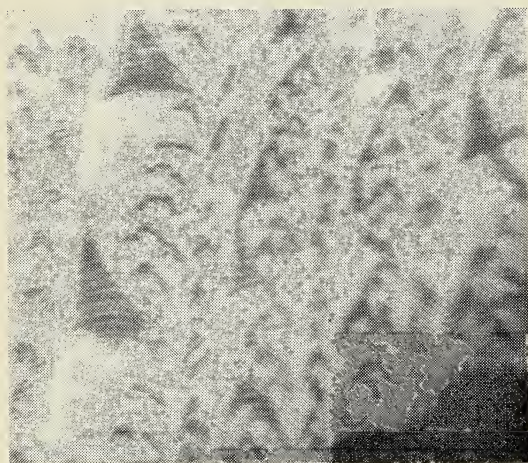


FIG. 5. Enlarged view of pattern on the shell of *Corculum*. The pattern is formed by the mosaic arrangement of transparent mass and non-transparent whitish mass.

#### LARVAL DEVELOPMENT

*Corculum* is a hermaphroditic animal. Development is indirect and it is remarkably rapid. Spawning was once observed on February 29, 1940, in the laboratory. A specimen collected on the previous day and cultured in a glass basin extruded eggs at 11 o'clock in the morning; by the end of 2 hours they had reached the two-cell stage. In the

evening they had become veligers and began to move. The next morning, all of them had grown to the two-valved stage and were swimming at the surface of the culture medium. They grew into the usual type of bivalve shells by the next evening, and settled to the bottom. Up to this time, there was no indication of the heart shape which is characteristic of this animal. There are no zooxanthellae in any tissue at this time. In what stage they attain the association with zooxanthellae is not yet known.

#### ASSOCIATION WITH ZOOXANTHELLAE

##### *Gills*

The normal position of the internal organs is somewhat displaced in accordance with the deformation of the shells. The organs are shown in Figures 6*a* and 6*b*. The gills and mantles are the most interesting. The gills are situated at both sides dorsally. They are short and narrow in figures, even in the photograph in the living state (Fig. 6). In the active state, however, they expand fully, just under the mantle, almost filling the whole mantle cavity. The length of the gill filaments of the inner lamella is much greater than that of the outer lamella, especially at the middle portion. This serves to fill the mantle cavity with gill filaments in the active state.

The gill is dark brown in the living animal. When it is examined under a microscope many zooxanthellae are found to be present in the filaments (Fig. 7*a*). The zooxanthellae do not seem to be enclosed in the host's cells.

##### *Mantle*

The mantle shows similar modifications in its structure and relative position. It forms a thin and heart-shaped mantle cavity. The mantle edges are fused at the middle of the upper side into an exhalant siphon; more ventrally they form an inhalant siphon, in the



living state, without showing morphological fusion.

The mantle of the upper side is pale and contains only a few zooxanthellae. The lower side, however, is dark brown in color due to the presence of the great accumulation of zooxanthellae. The difference is most striking at the folding line of the mantle from upper to lower surfaces as is shown in Figure 7*b*. The lower side is almost solidly dark but the upper side is only scattered with the zooxanthellae.

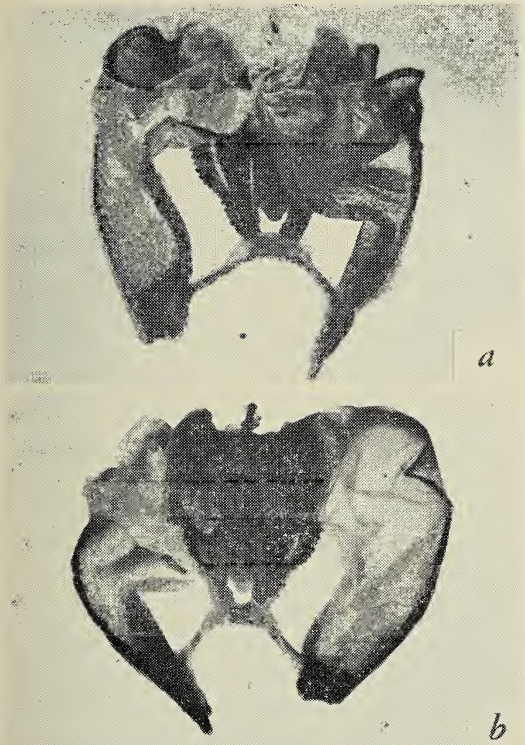


FIG. 6. *a*, *C. cardissa* with shell removed. Seen from lower side. The many dark spots are colonies of zooxanthellae. (Natural size.) *b*, Body of *C. cardissa* as seen from upper side. (Natural size.)

The mantle is extremely delicate and thin except at the edge. These relations may allow effective penetration of light to the gill filaments where the zooxanthellae are accumulated in great abundance. On the lower side, however, there is no need for the light to

penetrate through the mantle as there are no more zooxanthellae beneath the mantle.

There are many pigment granules on the outer surface of the mantle. They are blue, reddish-purple, or red in color, with significant fluorescence. They are a little larger than the dimensions of zooxanthellae. Whether these pigment granules may act as a filter for too strong light is not clear.

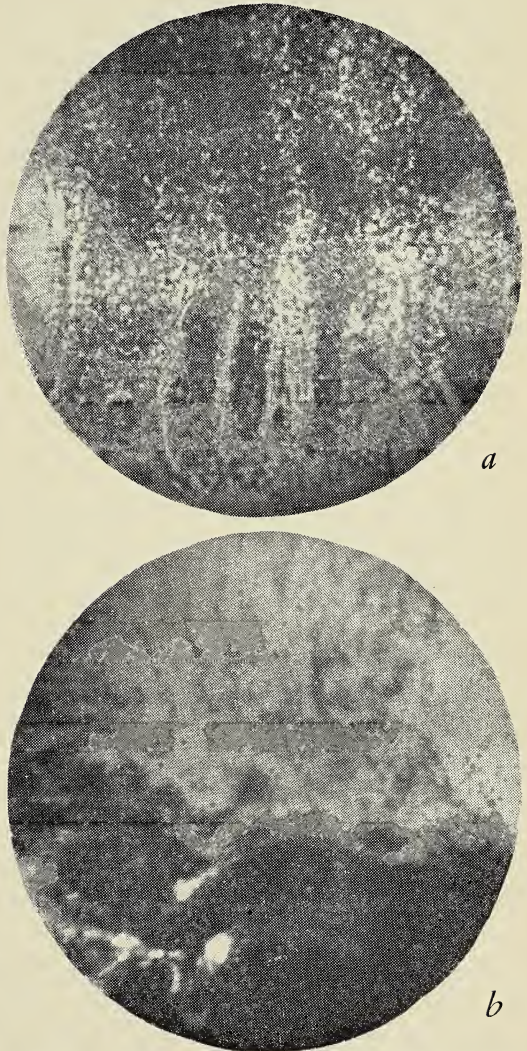


FIG. 7. *a*, Gill filaments of *Corculum* in living state, showing a full accumulation of zooxanthellae in them. A series of cilia is seen on each gill filament. *b*, A part of folding zone of mantle showing the great accumulation of zooxanthellae in the lower portion (seen evenly dark) and the lesser scattering in the upper portion.



### Digestive organ

Many zooxanthellae occur in the lobes of the liver, as is shown in Figure 8. There are many grades of disintegration of zooxanthellae. From this fact one may conclude that the zooxanthellae are used as food although how they pass into the liver from gills or mantle is not clear.

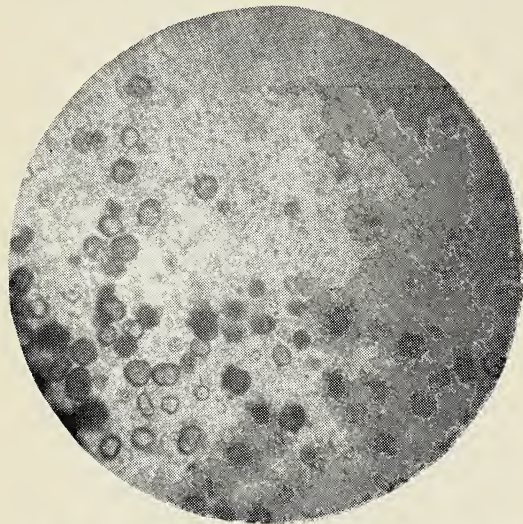


FIG. 8. Enlarged view of the content of the liver. There are many grades of disintegration of zooxanthellae in vesicles, probably phagocytic or digestive cells.

### Oxygen consumption

In order to determine whether or not these symbiotic zooxanthellae have an effect on the physiology of *Corculum* the oxygen consumption in the light and in total darkness was measured. Two animals weighing about 15 grams each were placed in glass jars of about 400 cc. capacity. These were immersed in

sea water and sealed with stoppers without leaving any air bubbles in them. They were first kept in total darkness in a simple thermostat containing sea water. In the second experiment they were exposed to the sunshine in the same thermostat on the grass land of the laboratory.

Oxygen tensions of the medium were measured at the beginning and the end of the experiment by Winkler's method. An injection syringe of 5 cc. capacity was used for an analyzing vessel. Details of the results are given in Table 2.

There was marked increase of the oxygen tension in the light. These increases are certainly caused by the photosynthesis carried on by the zooxanthellae contained in the gills and mantles. The amount of increase is comparable with that shown by reef corals.

The oxygen consumption while the animals were in total darkness is in the usual range for mollusks.

### COMPARISON WITH THE TRIDACNIDAE

It is very interesting to compare these observations with the data recorded for *Tridacna crocea*, in which even in the light no significant changes in oxygen exchange were observed (Yonge, loc. cit.) owing, probably, to the great bulk of tissues for the amount of zooxanthellae present.

This would indicate that there is no need of zooxanthellae for the oxygen requirements of the animal. Moreover there is a sufficient water current to remove excretory substances. One may conclude therefore that zooxanthellae may be used only for food.

TABLE 2  
OXYGEN CONSUMPTION OF *Corculum* IN TOTAL DARKNESS AND IN SUNLIGHT AT 28.5°–31° C.

CONDITION	WEIGHT	DURATION OF EXPERIMENT	O <sub>2</sub> INITIAL	O <sub>2</sub> FINAL	TOTAL DIFFERENCE	DIFFERENCE PER HOUR PER GRAM
	gm.	min.	cc.	cc.	cc.	cc.
Dark . . .	15.8	70	4.02	3.13	— 0.35	— 0.019
Light . . .	15.8	40	3.90	4.84	0.37	0.035
Dark . . .	15.9	70	4.02	3.24	— 0.32	— 0.017
Light . . .	15.9	40	3.90	4.94	0.43	0.041



The Tridacnidae have thick, heavy shells and usually rest on the hinge and umbo. Moreover, they culture immense numbers of zooxanthellae in the mantle edge which is exposed to the sunlight. Consequently the relation of the mantle and shell to the other organs is greatly different from in *Corculum*. The Tridacnidae may be divided into two groups according to their mode of life; one is a surface living species and the other a boring species. However, they both can attain immense size of shell in tropical seas where nutritive plankton is rather rare.

Yonge (loc. cit.) considered that the presence of associated algae may enable the Tridacnidae to exceed the limits normally set to the size of a plankton-feeder and thus be

responsible for the immense size attained by *T. derasa*.

It would seem then that the presence of associated algae induces the immense size of shell in *Tridacna* but results in the thin and rather transparent shell of *Corculum*. However, the presence of the algae may not be the primary factor in the formation of the large shell in *Tridacna*, but it may have served to allow the greater development of an evolutionary tendency. That is, in the Tridacnidae it perhaps accelerated a tendency to settling into the reef with a heavy shell, whereas in *Corculum* it would seem to have accelerated a tendency toward expansion of a thin transparent shell.

# Annual March of Daily Mean Temperatures at Honolulu

HAROLD S. PALMER<sup>1</sup>

THE PRESENT PAPER attempts to answer objectively the recurring question as to when the warmest and coldest weather occurs at Honolulu. For basic data the "daily mean temperature," which is the arithmetic mean between the maximum and minimum temperatures recorded during the 24-hour day, was chosen. It is usually reported to the nearest whole degree, since the temperatures used for its computation are not reported in fractions of a degree. If the arithmetic mean ends in five-tenths of a degree, it is arbitrarily rounded to the nearest even degree, whether this involves rounding up or rounding down.

In 1931, Mr. John F. Voorhees, then meteorologist of the Honolulu office of the U. S. Weather Bureau, supplied me with averages of the daily mean temperatures for each of the 365 days of the year. These covered the 41-year period from 1890 to 1930, inclusive. I do not know where the instruments were located from 1890 through 1904. From 1905 to 1922 the records were made on the Young Hotel Building, 121 feet above the ground, and since 1922 on the Federal Building, 99 feet above the ground. The difference in stations is not significant for the present study since it compares the averages for each date of the year and does not compare data from earlier and later periods. Leap day has been omitted from consideration.

Mr. Harry T. Tanaka, a student at the University of Hawaii, working on N. Y. A. funds, tabulated the daily means for the 10-year period from 1931 through 1940, and I have added the data for the 7 years from 1941 through 1947, thus getting the average daily mean temperatures for each of the 365

dates for the 58-year period from 1890 through 1947. The averages were calculated to tenths of a degree and are given in Table 1 and are shown graphically in Figure 1.

A study of the data for the 53-year period from 1890 to 1942 was reported to the Hawaiian Academy of Science in 1943 (Palmer, Harold S., *The Annual March of Daily Mean Temperature at Honolulu*. [Abstract.] *Hawaii. Acad. Sci., Proc.* 1945: 3). For that study a number of ways of smoothing and otherwise treating the raw data were tried. The method finally chosen as most satisfactory was that of 7-day progressive means, and is used in the present study. The method is this: the values for seven consecutive days are added, the sum is divided by seven, and the quotient is used for the middle, or fourth, day of the seven. The resulting 7-day progressive means are given in Table 2 and are shown graphically in Figure 2.

## THE COLDEST DATE

The data show that February 12, 13, and 14 have the lowest smoothed temperatures, namely 70.9° F. It is reasonable to suppose that February 13 is the coldest of the three, and this is confirmed by the fact that it is the coldest date among the unsmoothed data. Calculation of the smoothed values to hundredths of a degree further confirms this choice since the values for February 12, 13, and 14 are 70.92°, 70.91°, and 70.93°, respectively. It must be admitted that working to hundredths of a degree is unwarranted since the raw data were taken only to the nearest whole degree; but the calculation is given for what it may be worth.

A disagreement is found in the data for the 17-year period, 1931–1947, similarly

<sup>1</sup>Department of Geology, University of Hawaii. Manuscript received May 27, 1949.



TABLE 1  
FIFTY-EIGHT-YEAR DAILY MEAN TEMPERATURES. AVERAGED, BUT NOT SMOOTHED

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1	72.5	71.3	71.8	72.5	74.2	76.1	77.2	78.3	78.2	78.1	76.3	74.1
2	72.0	71.6	71.5	72.4	74.0	75.9	77.3	78.0	78.5	78.1	76.0	74.0
3	71.7	71.8	71.7	72.6	74.2	76.2	77.4	78.1	78.5	77.8	76.0	73.8
4	71.6	71.4	71.2	72.4	74.1	76.1	77.5	78.3	78.5	77.4	76.2	73.8
5	71.7	71.5	71.4	72.3	74.0	76.3	77.2	78.5	78.5	77.4	75.9	73.8
6	71.6	71.5	71.3	72.6	74.0	76.3	77.2	78.6	78.2	77.4	75.9	73.5
7	71.8	71.5	71.4	72.5	74.2	76.2	77.4	78.4	78.2	77.7	75.4	73.6
8	71.7	71.3	71.3	72.4	74.6	76.2	77.5	78.4	78.5	77.3	75.2	73.3
9	71.7	71.2	71.4	72.6	74.4	76.3	77.6	78.4	78.7	77.3	75.6	72.9
10	71.4	71.1	71.1	73.1	74.2	76.5	77.7	78.3	78.4	77.2	75.6	73.1
11	71.7	71.2	71.2	72.8	74.5	76.6	77.4	78.3	78.4	77.4	75.4	73.2
12	71.6	70.9	71.2	72.8	74.7	76.7	77.5	78.3	78.3	77.2	75.2	72.7
13	71.3	70.5*	71.2	73.1	74.4	76.7	77.5	78.5	78.0	77.1	75.2	72.3
14	71.2	70.7	71.6	73.4	74.9	76.9	77.6	78.3	78.1	77.0	74.8	72.8
15	71.0	70.8	71.5	73.2	75.0	76.6	77.8	78.3	78.3	77.4	74.5	72.9
16	71.0	71.1	71.8	73.4	74.9	76.7	77.8	78.5	78.2	77.4	74.7	73.0
17	71.1	71.3	71.6	73.4	75.2	77.0	78.0	78.4	78.3	77.1	74.6	72.5
18	71.7	71.5	72.0	73.6	75.2	76.9	78.0	78.5	78.2	76.9	75.0	72.7
19	71.7	71.4	72.0	73.4	75.3	76.9	78.0	78.8†	78.1	77.0	74.8	72.8
20	71.2	71.4	72.1	73.1	75.4	76.8	78.1	78.2	78.1	77.0	74.4	72.8
21	71.3	71.5	71.9	73.3	75.5	76.8	78.0	78.4	77.9	76.9	74.1	72.7
22	71.3	71.8	71.9	73.5	75.4	77.0	78.0	78.5	77.6	76.5	74.2	72.6
23	71.6	71.6	72.1	73.3	75.5	77.0	78.0	78.5	78.0	76.5	73.8	72.7
24	71.3	71.9	72.2	73.6	75.5	77.2	78.0	78.5	78.1	76.5	73.8	72.5
25	71.2	71.9	71.9	73.8	75.7	77.1	78.1	78.4	78.3	76.5	74.0	72.2
26	70.9	71.5	71.8	73.9	75.5	77.2	78.1	78.4	78.1	76.5	73.6	72.4
27	71.1	71.4	71.6	74.0	75.6	77.3	78.2	78.4	77.9	76.7	74.2	72.4
28	71.1	71.1	71.7	74.0	75.7	77.5	78.2	78.4	77.8	76.2	73.7	72.3
29	71.0	.....	72.2	73.7	75.8	77.2	78.2	78.3	78.1	76.2	73.8	72.5
30	71.3	.....	72.2	73.8	76.0	77.2	78.2	78.3	77.8	76.5	73.7	72.1
31	71.3	.....	72.1	.....	75.9	.....	78.1	78.4	.....	76.6	.....	72.3

\*Coldest date. †Warmest date.

smoothed. The coldest dates in February for this period are the tenth, eleventh, and twelfth, with smoothed values of 71.6°, but there are colder dates in March, namely March 7 to 13, with smoothed temperatures

of 71.5°, 71.4°, 71.3°, 71.3°, 71.4°, 71.4°, and 71.5°, respectively. The graph of the smoothed temperatures for the 58-year period (Figure 2) has a secondary trough from March 8 to 11, with 71.3° on the four days.

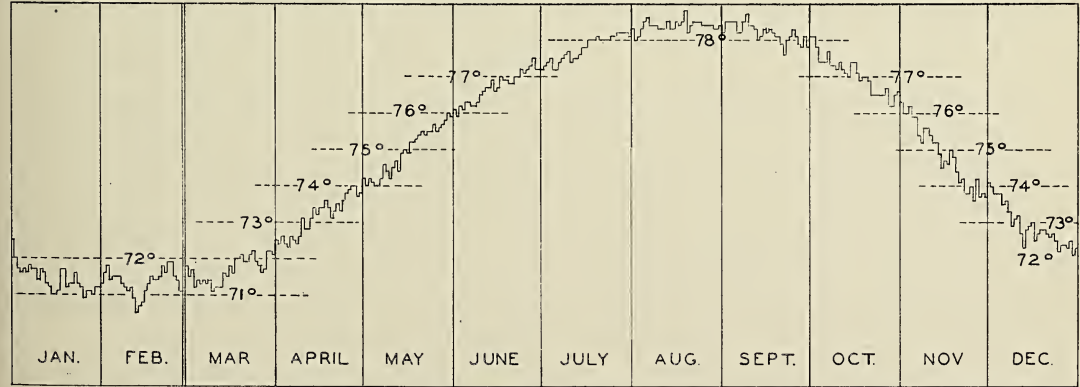


FIG. 1. Averages of daily mean temperature at Honolulu; not smoothed; 58 years, 1890 to 1947.

## A POSSIBLE RHYTHM

From about January 10 to March 20 there are several fluctuations with ranges of about  $0.6^\circ$ . For most regions  $0.6^\circ$  would not be significant, but it might be significant for Honolulu where the conventional "mean annual range of temperature" is only  $6.8^\circ$  ( $78.3^\circ - 71.5^\circ$ ) and the extreme range is only  $38^\circ$  ( $90^\circ - 52^\circ$ ). Therefore a study was undertaken of the fluctuations in the first 3 months of each of the 18 years from 1931 to 1948. The value of  $0.6^\circ$  is about 9 per cent of the  $6.8^\circ$  mean annual range and is about 1.6 per cent of the extreme range. Inspection of Figure 2 shows troughs with center dates of January 16, January 28, February 13, and March 8 or 9. Eighteen sets of 7-day progressive means were computed for the first 3 months, one set for each of the 18 years. These means were plotted as 18 graphs, and were inspected to see to what extent there were troughs that coincided with one another and with the troughs of Figure 2.

In Figure 2 there are four more or less definite troughs and four or five more or less definite crests between January 1 and March 31. The 18 graphs for the 18 years show from three to six troughs and from two to six crests, their distribution being shown in the following tabulation.

Frequency of Numbers of Troughs and Crests  
per Year

I	II	III
2	0	1
3	5	2
4	5	5
5	7	6
6	1	4

- I. The number of troughs (or crests) per year.
- II. The number of years with the number of troughs indicated in I.
- III. The number of years with the number of crests indicated in I.

The frequencies shown in the tabulation differ so much from the numbers of troughs and crests in Figure 2 that they make untenable the idea that some meteorological rhythm causes the troughs and crests of Figure 2.

Moreover, if there were some rhythmic cause that repeated in a significant number

of the 18 years, we ought to find recurrences of troughs and crests on or about the same dates. A table was prepared with (a) the 84 days for which 7-day progressive means were calculated and (b) the 18 years as arguments. Each trough or crest was entered in the body of the table at the proper date and year. Only a few dates gave more than 3 years with either troughs or crests. January 5 with four crests and February 21 with five crests were the highest, but neither of these dates is noteworthy in Figure 2. January 21 had four troughs but also had one contradictory crest, and is moreover close to a crest in Figure 2. February 16, which follows by 3 days the trough of Figure 2, had three crests in the 18 years. The data for January 21 and February 16 definitely contradict the hypothesis of a rhythmic control.

Smoothed averages for the 41-year and the 17-year periods showed no exact coincidences of troughs and crests with one another, nor with the 58-year graph of Figure 2. So we conclude that there is no evidence of an annually recurring, rhythmic cause to explain the troughs and crests of Figure 2. No doubt the troughs and crests of graphs for single years are due to the influence of fronts related to highs and lows that pass near enough to affect Honolulu's weather. There certainly is no mystic relationship to the winter solstice.

## THE WARMEST DATE

Selection of a warmest date is less simple because the smoothed values form a sort of plateau of 36 days, including 30 dates of  $78.4^\circ$ , with 2 dates a tenth of a degree lower and 4 dates a tenth of a degree higher. Among the 7-day progressive means for the 58-year data, we find  $78.5^\circ$  on August 16, 19, 20, 21, and 22, with  $78.4^\circ$  on August 17 and 18. The 7-day progressive means were subjected to a second, similar smoothing, which gave a series of five dates, August 18 to 22, with  $78.5^\circ$ . The middle date is August 20, which may therefore be taken as the warmest date.



TABLE 2  
ANNUAL MARCH OF DAILY MEAN TEMPERATURES AT HONOLULU, 58-YEAR DATA, 1890-1947.  
SMOOTHED AS 7-DAY PROGRESSIVE MEANS

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1	72.1	71.4	71.5	72.3	74.0	76.0	77.3	78.2	78.4	77.9	76.3	73.8
2	72.0	.5	.4	.4	.0	.1	.3	.2	.4	.8	.2	.9
3	71.9	.5	.4	.4	.0	.1	.3	.3	.4	.7	.1	.8
4	.8	.5	.5	.5	.1	.2	.3	.3	.4	.7	76.0	.7
5	.7	.5	.4	.5	.2	.2	.4	.3	.4	.6	75.8	.7
6	.7	.5	.4	.5	.2	.2	.4	.4	.4	.5	.7	.5
7	.6	.4	.3	.6	.2	.3	.4	.4	.4	.4	.7	.4
8	.7	.3	.3	.6	.3	.3	.4	.4	.4	.4	.6	.3
9	.6	.2	.3	.7	.4	.4	.5	.4	.4	.4	.5	.2
10	.6	.1	.3	.8	.4	.5	.5	.4	.4	.3	.4	73.0
11	.5	71.0	.3	72.9	.5	.6	.5	.4	.3	.2	.3	72.9
12	.4	70.9	.3	73.0	.6	.6	.6	.3	.3	.2	.2	.8
13	.3	.9	.4	.1	.7	.7	.6	.4	.2	.2	75.1	.9
14	.3	70.9	.4	.2	.8	.7	.7	.4	.2	.2	74.9	.8
15	.3	71.0	.6	.3	74.9	.8	.7	.4	.2	.2	.9	.7
16	.3	.0	.7	.4	75.0	.8	.8	.5	.2	.1	.8	.7
17	.3	.2	.8	.4	.1	.8	77.9	.4	.2	.1	.7	.8
18	.3	.3	.8	.3	.2	.8	78.0	.4	.2	.1	.6	.8
19	.3	.4	.9	.4	.3	.9	.0	.5	.1	77.0	.5	.7
20	.4	.5	71.9	.4	.4	.9	.0	.5	.0	76.8	.4	.7
21	.4	.6	72.0	.4	.4	76.9	.0	.5	.0	.8	.3	.7
22	.4	.6	.0	.4	.5	77.0	.0	.5	.0	.7	.2	.6
23	.3	.7	72.0	.5	.5	.0	.0	.4	.0	.6	.0	.6
24	.2	.7	71.9	.6	.5	.1	.1	.4	.0	.6	74.0	.5
25	.2	.6	.9	.7	.6	.2	.1	.4	.0	.5	73.9	.4
26	.2	.6	.9	.8	.6	.2	.1	.4	.0	.4	.8	.4
27	.1	.6	.9	.8	.7	.2	.1	.4	.0	.4	.8	.3
28	.1	71.6	71.9	.9	.7	.2	.2	.4	.0	.5	.9	.3
29	.1	-----	72.0	73.9	.8	.3	.2	.3	78.0	.4	.9	.4
30	.2	-----	.1	74.0	.9	77.3	.2	.4	77.9	.4	73.9	.3
31	71.3	-----	72.2	-----	75.9	-----	78.2	78.4	-----	76.3	-----	72.2

In the unsmoothed data, August 19, with 78.8°, is the warmest.

If the raw data are smoothed to hundredths as 7-day progressive means, we get August 21, with 78.50°, as a trifle warmer than any other date.

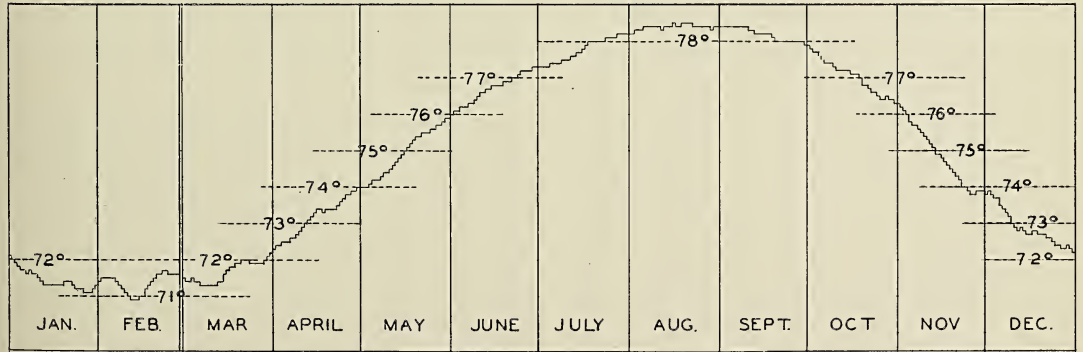


FIG. 2. Averages of daily mean temperature at Honolulu; smoothed as 7-day progressive means; 58 years, 1890 to 1947.

The 41-year data, reported on in 1943, smoothed to hundredths as 7-day progressive means, gave September 6, with  $78.51^{\circ}$ , as the warmest date. The 17-year data gave a run of 7 days with  $78.6^{\circ}$ , from August 16 through August 22. From these, August 19 may be taken as the warmest date, and agreeing well with the August 20 date from the 58-year graph.

The 36-day long "plateau" of Figure 2 was subjected to further study by means of 18 graphs of 7-day progressive means, from July 15 through September 25, for the 18 years from 1931 through 1948. On these graphs there were found a total of 43 dates which either had the maximum temperature for the year in question or were tied for the maximum. They ranged from as early as July 22 to as late as September 25, a range of 65 days. The mean and median dates were both August 23. The standard deviation was 14.5 days, a large value that implies uncertainty as to the date of the mean. Inspection of the 18 graphs showed a great variation—some were relatively smooth and some rather "wavy"; some showed a single maximum and some showed several scattered dates tying for the maximum; and, of course, the dates of the maxima varied greatly as described above.

The plateau of 36 days duration contrasts strongly with the wavy curve of the first months of the year. The difference is thought to be due to differences in the altitudes of the noon sun. In winter the altitude of the noon sun decreases steadily to a minimum about December 21 and then increases steadily. But in summer the noon sun on two occasions crosses the zenith of Honolulu, in  $21^{\circ} 18' \text{ N. Lat.}$  The noon sun is nearest the zenith about May 26 and again about July 16. On about June 21 the noon sun is  $2^{\circ} 9'$  north of the zenith, and it is the same amount south of the zenith about May 16 and July 26. Thus for the period of 71 days between these two dates the noon sun is very high. During this time, also, the length of the daylight day

varies only 17 minutes—that is, from 13 hours and 9 minutes to 13 hours and 26 minutes. Thus there is a long period in which the insolation is not only strong but is very uniform, which uniformity may well explain the plateau or long sequence of days of uniformly high average temperatures.

#### LAGS

If we select February 13 as the coldest date, we find that it falls 54 days after the winter solstice. Similarly, August 20 falls 60 days after the summer solstice. These dates divide the year into somewhat unequal parts. It takes 188 days to warm up from the coldest to the warmest date, but only 177 days to cool down again.

The most rapid cooling is from November 1 to November 26, during which time the 7-day progressive means drop  $2.5^{\circ}$ , from  $76.3^{\circ}$  to  $73.8^{\circ}$ , or at a rather steady rate of a tenth of a degree per day.

A longer period of fairly steady warming up extends from March 28 to June 15, with a rise of  $4.8^{\circ}$ , from  $72.0^{\circ}$  to  $76.8^{\circ}$ , in 78 days, or at a rate of about  $0.06^{\circ}$  per day. This period of rising temperature is not as steady or as rapid as the drop in November, but a short period of 10 days, from May 10 to May 20, gives a steady rise of about a tenth of a degree per day.

#### CONCLUSIONS

We have been considering only one element of the weather, namely the physical temperature, but the impression that the human animal gets of temperature is strongly modified by the effects of air movement and of humidity.

It appears that, on the average, the coldest date is February 13 and the warmest date is August 20. But, despite the alleged monotonous uniformity of Hawaiian weather, the dates of warmest and coldest temperature in any one year may come as much as a month earlier or later than the average dates. It also appears that the cold season may include several irregular fluctuations of temperature.



## The Birds of Yap, Western Caroline Islands

HARVEY I. FISHER<sup>1</sup>

THE YAP GROUP of islands, which lies about 450 miles southwest of Guam and 125 miles northeast of the Palaus, is composed of four main islands: Rumung, Map, Gagil-Tomil, and Yap. There are several islets in the lagoon between Yap and Tomil islands.

The highest elevation (585 feet) is in the north-central part of Yap Island (Fig. 1). Except for this hilly area, the rest of Yap Island is below 200 feet. All of Gagil-Tomil is below the 200-foot elevation, and the highest parts of Map and Rumung are from 250 to 300 feet above sea level. The greatest length of the group is about 16 miles and the greatest width is 6.5 miles.

Ulithi atoll is the nearest land mass, lying about 90 miles to the northeast. To the southwest are the Palaus. Thus, Yap lies in a chain of islands from the Palaus in the south to the Marianas in the north. None of the islands in the chain is widely separated from the others. Furthermore, to the east is the whole group of Caroline Islands. Because these islands seem to form a perfect series of "stepping stones" for the movement of plants and animals from the southwest Pacific to the north Pacific through the Marianas and eastward through the Carolines to the central Pacific Ocean, it was deemed desirable to study birds of Yap, especially since the extensive work of the Whitney-South Seas Expeditions did not include Yap, and no modern collections of birds from this area are known.

Preliminary investigation and collections were made on Yap from July 28 to August 24, 1946. A total of 148 vertebrate specimens were taken: 17 amphibians, 28 reptiles, 9 mammals, and 94 birds. No attempt

was made to collect large series of any species; rather an attempt was made to secure representatives of all species present. Records of the reptiles and amphibians taken have been published (Fisher, 1948).

The University of Hawaii sponsored this trip. I wish to acknowledge the aid of the United States Navy in furnishing transportation and other facilities. In particular, I wish to thank Captain O. M. Murphy, United States Navy Commander of the Yap Area, for use of various facilities at Yaptown and for his interest in the project. I also want to thank Mr. Eveni Levi of Tutuila, American Samoa, who accompanied me from Honolulu; he helped greatly in many ways. Dr. Ernst Mayr has checked the identification of all species discussed and has made critical taxonomic comments, many of which are included in the species accounts.

It is no longer possible for me to continue these studies. Hence, it seems worth while to put on record the observations of this brief survey.

As indicated above, the islands are relatively low. They are almost completely covered with vegetation. Yap and Rumung show a similar zonation of vegetation. On the inner side (toward the lagoon) these islands have extensive swampy areas, and mangroves of two kinds form dense thickets at the water's edge. On the outer side the islands have large areas of shallow water inside the coral reef. For the most part, these have coral and rock substrata with little mud. At the upper ends of the tidal swamps on the lagoon side are semi-open mudflats. Above these swamps or mudflats, or above the narrow beach on the sea side, the dense jungle starts immediately and continues upward to an

<sup>1</sup>Department of Zoology, University of Illinois, Urbana. Manuscript received April 28, 1949.

elevation of about 200 to 250 feet on the southern end of Yap Island; on the northern end of Yap Island the hilly regions have dense stands of trees, but here and there are open areas of grassland with scattered *Pandanus* trees. Most of the rolling region to the south is this same type of savanna. The central part of Rumung is much the same.

Perhaps because of their lower elevation, Map and Gagil-Tomil islands do not have these open areas. The usual swamps and mangroves are present as a fringe about the circumference, but tall trees cover most of the rest of the surface.

In the discussion of the species, the habitats will be mentioned as mangroves, swamps, jungle, or savanna, referring to the various situations described above. An asterisk indicates that specimens were taken.

*Puffinus pacificus*, Wedge-tailed Shearwater.\*—Five were observed flying over the south entrance to Tomil Harbor.

*Puffinus l'herminieri*, Dusky Shearwater.—Only one was seen, at the north end of Rumung Island.

*Phaethon lepturus*, White-tailed Tropic Bird.—Twos and singles were observed several times over Map Island.

*Fregata ariel*, Least Man-o'-War Bird.—Observed at close range at Yaptown (one bird) and at Balabat (three), August 6 and 13, respectively. Nine flew over Balabat on August 15. Natives reported that the species sometimes nested on Yap Island. The bird is closely associated with native traditions and customs, such as ceremonial dances, in which its feathers are used as ornaments. Identification was made of one roughed-out skin used as a headdress.

*Sterna fuscata*, Sooty Tern.—On July 30, six birds were resting on the beach at the north end of Rumung Island.

*Sterna lunata*, Gray-backed Tern.\*—One collected from a flock of nine *Thalasseus bergii* off Orila, Map Island.

*Thalasseus bergii*, Crested Tern.\*—Nine individuals were observed on tops of pilings of an abandoned fish trap off Orila, Map Island.

*Gygis alba candida*, Fairy Tern.\*—This species was abundant on all the islands in those places where there were tall trees some distance apart. It was not seen in the deep jungle growth or in the savanna areas and was most frequently observed in the tall breadfruit, banyan, and coconut trees and in tall, isolated mangrove trees in the swamps. I did not find it in low shrubs such as are used by *G.a. rothschildi* in the western Hawaiian islands.

Also in contrast to *rothschildi*, *candida* was very noisy at night. This constant calling was observed on three occasions, at 9:00, 10:30 P.M., and 12:15 A.M.

The fairy tern, like the man-o'-war bird, is frequently used as an ornament of dress. Three natives had outlines of this tern tattooed on their shoulders.

*Anous stolidus pileatus*, Common Noddy.\*—The noddy was found only on Tarang Island in Tomil Harbor. Here, an estimated 250 were seen, usually in the tops of pandanus, breadfruit, and chestnut trees. Old nests were found in the top whorls of pandanus trees, 12 to 18 feet from the ground. No nests were observed in higher or lower sites. Egg shells were found on the ground, indicating that nesting had occurred not long before. Some nests were apparently under construction, for they contained in their walls seaweed that was still green. Furthermore, two birds carrying strands of seaweed were observed flying into nests.

*Pluvialis dominica fulva*, Pacific Golden Plover.\*—In late July an occasional single or pair was observed. By August 15, they were quite numerous, 15 to 25 birds in 150 yards of beach, along the beaches, tidal flats, and marshes, but they did not fly or feed in flocks. They were also abundant in open areas of savanna and around the Nif airfield.



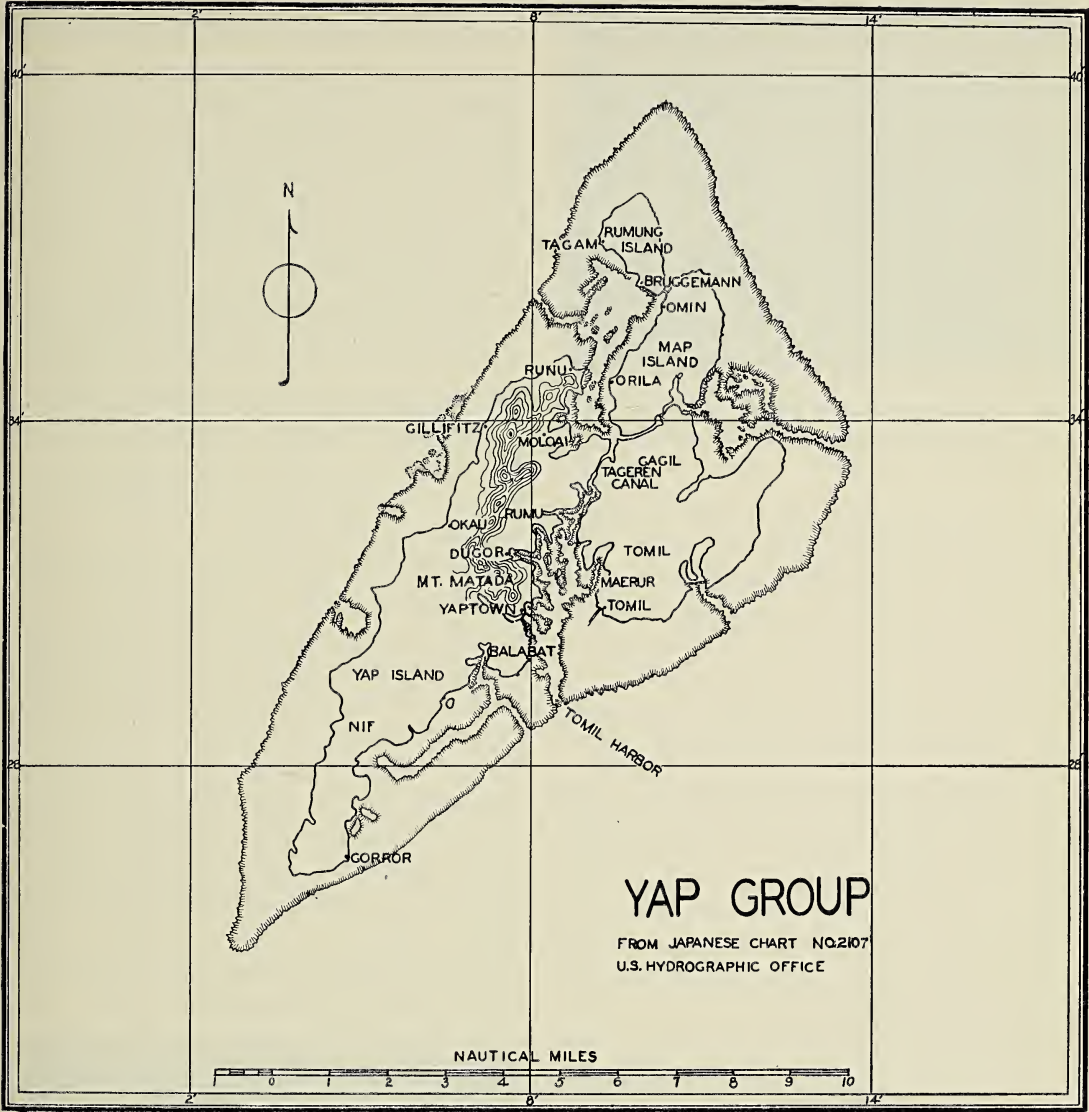


FIG. 1. The Yap Group of islands.

*Charadrius mongolus*, Mongolian Dotterel.\*—One was collected on the mud of a small taro patch in the jungle ½ mile west of Balabat.

*Numenius phaeopus variegatus*, Whimbrel.\*—Singles, pairs, and groups of three were commonly found on mudflats where there was no vegetation. Three were observed feeding on the grass-covered airstrip at Nif. No change in numbers was observed during our stay.

*Numenius tahitiensis*, Bristle-thighed Curlew.\*—Only two singles were observed, both on rocky beaches.

*Tringa glareola*, Wood Sandpiper.\*—One was collected on a mudflat at Moloai, Yap Island, August 10. No others were seen.

*Heteroscelus incanus brevipes*, Wandering Tattler.\*—As would be expected, several individuals were seen on rocky stretches of beach, but they were just as numerous on small mudflats and around small patches of



FIG. 2. Dense jungle growth, 150 feet elevation, Dugor, Yap Island. Habitat of *Rhipidura*, *Monarcha*, and *Myzomela*.

taro in the dense jungle. One was observed in an open area of the savanna region.

*Arenaria interpres*, Turnstone.\*—One flock of five and one flock of two were observed on Yap Island, August 6 and 16, respectively.

*Crocethia alba*, Sanderling.\*—Occasional individuals were found along the beaches.

*Demigretta sacra*, Reef Heron.—Of 14 individuals observed on beaches and mudflats from July 28 to August 16, 11 were dark gray, one was light gray, and two were white in color.

*Nycticorax caledonicus*, Rufous Night Heron.—Two were in the edge of jungle adjoining the Nif airfield.

*Ixobrychus sinensis*, Chinese Least Bittern.\*—These bitterns were most numerous around the water-filled bomb craters in the Nif airfield; on one occasion, 49 were seen in 4 hours. However, individuals were present around permanent and temporary rain-filled depressions in all parts of the islands. Each taro patch, no matter how small, had at least one bittern. They were abundant in the mangroves, in places a bird every 100 yards. Mayr (1945: 285) stated that this species was mostly nocturnal. I found it usually active in the daytime—feeding, calling, and flying about from one pond to another. Its call was not heard at night.

*Anas (superciliosa?)*.—The "dark, female mallard with white line above its eye," observed by Levi and me probably was *superciliosa*. It was on the saltwater lagoon just off Yaptown. Captain O. M. Murphy said that the birds were frequently seen around the craters in the Nif airfield and that they were present throughout the year, but I did not find them there.

*Gallus gallus*, Domestic Chicken.—A few semi-domestic fowl were found in the jungle near the native villages. I was told that before the war such feral chickens nested in many different places. During the naval blockade in the latter part of the war the Japanese military forces hunted down most of them for use as food.

*Poliolimnas cinereus collingwoodi*, White-browed Rail.\*—Mathews, in 1939, described the subspecies, *micronesiae*, and stated that Micronesian specimens were intermediate between *collingwoodi* from the Philippines and specimens from Vulcan Island. Examination of 32 specimens of "*micronesiae*" and a series of *collingwoodi* failed to substantiate his remarks. Mayr (in litt.) stated, "To this subspecies (*collingwoodi*) belong also the specimens from Talaut Islands, Palau, Guam, and Ruk. There are some characters peculiar to each locality but the differences between populations of these islands

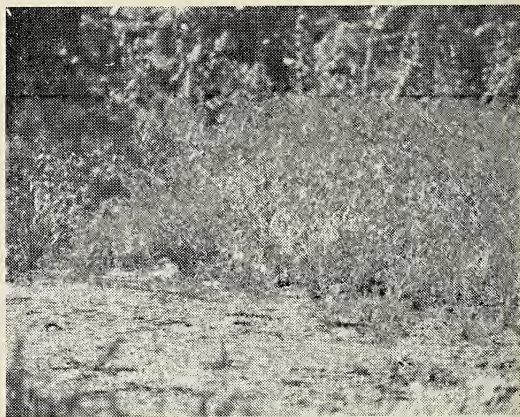


FIG. 3. Grassy swamp, 20 feet elevation, Rumu, Yap Island. Habitat of *Poliolimnas cinereus*.



are not sufficiently constant and conspicuous to permit separation from *collingwoodi*."

These rails were present in all suitable taro patches or marshy areas that were investigated. They were not found in saltwater marshes but were present in marshes of brackish water less than 200 yards from the sea and only 2 to 5 feet above sea level. All areas found to be occupied by this species had three things in common: mudflats, shallow water (2 to 4 inches), and clumps of heavy marsh grasses.

Apparently the size of a taro patch has little to do with the number of rails present. I never found more than one pair in any isolated marsh or taro patch, and I investigated 13 such places, ranging in size from circular areas 50 feet in diameter to swamps containing 3 to 5 acres. A pair was collected from each of two smaller taro patches; during the following 3 weeks no rails were seen there, although the areas were visited every other day during that time. On two occasions individuals were flushed from dense grass some 50 yards from swampy areas. On both occasions the birds flew strongly and swiftly to cover in the swamp. I never saw this species more than 5 feet from heavy, grassy cover.

Two trips were made at night to areas in which rails fed in the daytime. In 4½ hours of observation no birds were seen and no calls were heard.

At Balabat, at 10:30 A. M., on August 11, I saw an adult run across a small opening in the middle of an abandoned taro patch overgrown with water grass. A few seconds later another adult followed; it was collected. When I retrieved the bird I found I had also collected a chick. At 2:30 P. M. on August 12 in a similar area, I watched two adults and a brood of four chicks feeding in water 1 inch deep. During the entire 40 minutes this group was watched, both adults kept their tails up in the air and jerked them vertically at 5-second intervals. They kept in a close



FIG. 4. Elevated trail in sea level swamp, Balabat, Yap Island. Habitat of *Ixobrychus* and *Poliolimnas*.

group, except for occasional straying by a chick; when a chick strayed the parent called, *k-uk, k-uk, k-uk*, in contrast to the usual, hard, *kuk, kuk, kuk*. So near to each other did these birds stay that I was able to collect all six with a single shot from a 410-gauge shotgun at a distance of about 25 yards.

The adults were a male and a female. The chicks were covered with black down. Their legs were dull blue. The distal third of both the upper and lower mandibles was dirty-ivory in color; the middle third, extending proximally to the middle of the external nares, was black. The basal third was washed-yellow. The call of these chicks, whose body length was 2 inches, was much like that of day-old domestic chickens, but finer, shriller, and weaker.

*Ducula oceanica monacha*, Micronesian Pigeon.\*—These were not numerous on the islands, but one could be certain of seeing five or six in a half-day. It was seldom seen in the savanna area, except at dusk when there was considerable movement between wooded regions. As a rule, the birds were first observed high in the barer branches of trees 30 to 60 feet in height, but one was collected while it rested on a nest some 20 feet from the ground in a breadfruit tree; the nest was old and empty. The call is a single *augh* or *ungh*.





FIG. 5. Typical taro patch swamp, Omin, Map Island. A pair of rails nested here.

*Gallicolumba xanthonura*, Ground Dove.\*

—Comparison of specimens from Yap and the Marianas revealed little significant difference. The only female from Yap was somewhat darker above and particularly darker below in the throat and breast; specimens from the Marianas are more rufous cinnamon in these parts of the body. Size seemed to be identical in the two series.

This species is uncommon on the island; I saw only 14 (singles, except for a male and a female collected together) in 4 weeks. It appeared to be limited to mangrove thickets in or near water and was not seen anywhere in the interior of Yap Island.

*Rhipidura rufifrons versicolor*, Rufous-fronted Fantail.\*—Mayr (in litt.) wrote as follows:

The Yap race which I had not previously seen is more distinct from the races of the Marianas Islands than I had expected. The extensive, buffy, ochraceous wash of belly and flanks is missing. The well-defined, clear, white upper throat is another striking difference as are the gray-brown flanks. The upperparts are darker and more rufous with the contrast between rump and back much less pronounced. Actually, the Yap bird is, in the coloration of its underparts, much more similar to the Solomon Islands races and in particular to *brunnea* from Malaita Island. It

differs from that race by the more extensive white tips on the tail feathers and broader white edges on the feathers of the breast and middle of the abdomen. The rufous zone on the lower back is more reduced. There is a more distinct grayish wash in the black portions of the tail feathers. The similarity is so striking that I wouldn't be surprised if Yap had actually been colonized from Malaita.

Although found on all the islands, they are most abundant on Tomil. The edges of low undergrowth in lowland jungles and the edges of mangrove swamps seemed to be favorite habitats, but a few were seen far back in the jungle. Without exception, the birds were found in twos or in family groups; three broods of nearly fledged young (three in each brood) were following pairs on August 11.

They are constantly on the move and are wary, but they, at this season at least, came in toward squeaking noises. They responded best to the sound of two pieces of seasoned wood being knocked together, as when ashes from a pipe were knocked out by hitting it against a gunstock. As one moved along a trail these birds frequently flew out ahead, displaying vigorously. They became most active just after sundown and before total darkness.

*Monarcha godeffroyi*, Monarch Flycatcher.\*—Specimens collected showed much individual variation in extent of the black, brown, and white coloration. Two birds in brown coloration, similar to *M. takatsukae* from Tinian, were taken. Both were adult females, on the basis of degree of ossification of the skull and development of the ovaries; one was feeding nearly grown young. Immatures collected were dirty-black or brownish-black with dirty-white markings. Males were white-backed with white ventra, and the females had a white ring of varying extent about the neck.

On all islands of Yap, the species was abundant along the trails in heavy jungle. In this habitat the species was usually found 20 or more feet up in the vegetation, not in



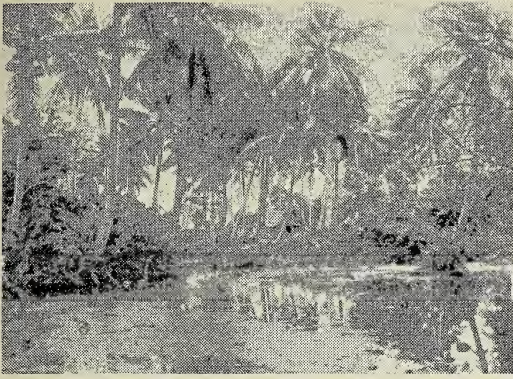


FIG. 6. Sea level swamp, Balabat, Yap Island. Habitat of *Poliolimnas* and *Ixobrychus*; in surrounding mangroves *Gallicolumba xanthonura* was collected.

the low understory as was *Rhipidura*. However, this flycatcher was also observed perched on bare pandanus limbs (10 to 20 feet high) in the savanna region; here, it flew out after insects in typical flycatcher fashion. Mayr (1945: 92) noted that this seldom occurred in *Monarcha*; he also stated that the tail drooped vertically as the bird perched motionless. The tail was never drooped in the monarchs of Yap.

*Aplonis opacus kurodai*, Micronesian Starling.\*—Three specimens from Yap agree fairly well with *orii* Takatsukasa and Yamashina from the Palaus, but the gloss on the birds from Yap seems to be more blue green, less bottle green; this may be due to slightly greater wear on the specimens from the Palaus. The bill seems slightly longer on the birds from Yap (Mayr, in litt.).

The species was abundant on all the islands in all types of cover except the savanna. Birds were most numerous, however, in the tops of high trees and were seldom, if ever, encountered in low, dense brush. The tops of coconut trees were much used as singing perches, and hau trees (*Hibiscus tiliaceus*) were frequented for their fruits. No nesting birds were found, but one juvenile was observed (August 7) begging and receiving food, and an adult was observed carrying food on August 16. As in

other places, this species is in frequent conflict with other species; on Yap, *Myzomela cardinalis* and *Monarcha* were the chief victims of this conflict.

*Myzomela cardinalis kurodai*, Cardinal Honey-eater.\*—It is unfortunate that the series of skins from Yap contained only one of a female, for the races are more clearly pronounced in the females. The one female agrees closely with an adult female *kobayashi* from Palau; both have distinct olive edges to the tail feathers, and the red is restricted to the top of the crown and does not extend to the nape; the comparative blackness of the scapulars in the Yap bird is perhaps due to its fresh plumage. The only difference between these two females is that the red of the crown and throat of the specimen from Yap is more cherry red, less scarlet, and there is a more pronounced zone without red between the upper throat and breast and between the crown and back. The wing and tail of the Yap race appear to be somewhat longer. The bill of the Yap birds appears to be longer than that of the Palau birds, but measurements do not confirm this visual impression. The edge of the newly molted primaries seems more olivaceous in Palauan than in Yap males. The under-tail coverts of birds from Yap seem blacker than in birds from Palau. On the basis of the specimens before me I would not be inclined to recognize *kurodai*, but it must be considered that the Yap series is in full molt. (Mayr, in litt.)

The honey-eaters were present in all suitable habitat on all islands. They were most abundant in low brush, no matter whether this brush was in the jungle, in otherwise open country, or in a mangrove swamp. In their brush habitat the birds appeared to be weak flyers, their fluttery flights seldom longer than 15 feet, but on August 21 one was observed over the center of Tomil Harbor, more than  $\frac{1}{2}$  nautical mile from land.

As a rule, they were observed in pairs, but on August 7 a brood of three was following



a pair. On August 10, a female (collected) was starting a nest in the outer tips of a branch some 10 feet from the ground. Another female (collected, but unfit for a specimen) was observed carrying food on August 10.

*Zosterops conspicillata hypolais*, Bridled White-eye.\*—The Yap subspecies, *hypolais*, is strikingly different from all the other races of the species. It is by far the most grayish race of the species. The eye-ring is inconspicuous and the dark area under the eye is grayish rather than blackish. The white loreal region is much reduced. The upperparts are gray, with a greenish tinge, most conspicuous on rump and crown. The underparts are somewhat like those of *rotensis* but slightly more yellowish, less buffy, particularly on the flanks. The size seems the same as in most other races of this species in which the wing varies between 55 and 58 millimeters in length in adult males. (Mayr, in litt.)

This species was usually confined to the undergrowth at the edge of the jungle. One could find it in numbers from 2 to 15 in almost every such area 100 yards long.

*Rukia* [Kubaryum] *oleaginea*, Large Yap White-eye.\*—This species differs from the related *Zosterops conspicillata* by being larger, darker, and more brownish olive. "In general coloration it is remarkably similar to *sanfordi* from Ponape. It is somewhat darker, particularly on the crown, forehead, and lores. There is an extensive blackish zone in the malar region and under the eyes, which is barely indicated in *sanfordi*. The underparts also are darker and more grayish, while in *sanfordi* they are more brightly greenish buff. Rump and tail, as well as the edges of the primaries and secondaries, are duller. The legs are duller, more grayish horn color rather than yellow as in *sanfordi*. The two principal

differences between the two species are, however, in the shape of the bill, which is nearly twice as long as in *sanfordi*, and in the eye-ring which is obsolete in *sanfordi*. The exposed culmen measures about 14 millimeters in *oleaginea* and over 20 in *sanfordi*." (Mayr, in litt.)

In the month spent on Yap, only two individuals were observed; one on August 6, 1 mile northwest of Yaptown, Yap Island, and one on August 7, less than ¼ mile from the same area. One was in a bush overhanging a swamp in dense jungle, and the other was in low, thick underbrush 200 yards from a swamp.

*Lonchura punctulata*, Weaver-Finch.\*—The three skins agree best with a series of the race *cabanisi* from the Philippines. They are also rather similar to the race *topela* from the Asiatic mainland but are distinguished from this subspecies by the fine barring on their flanks and by a less extensive brown area on the throat. (Mayr, in litt.)

This weaver-finch was found in all open and grassland areas on the islands. Flocks of 40 were observed in the shorter, dry grass of the savanna regions, and they were especially numerous in flocks of 5 to 20 birds along grassy roads and wide trails where they were feeding on seeds. Some immatures were begging for and receiving food on August 16.

This species probably was introduced on Yap.

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# The Marine Algal Communities of Stanmore Bay, New Zealand (Studies in Inter-tidal Zonation 1.)

V. J. CHAPMAN<sup>1</sup>

## INTRODUCTION

THE MAIN PURPOSE of the present and subsequent studies is to obtain a picture of the algal vegetation on different types of shores in the Auckland province, and to correlate, if possible, the observed zonation with the principal features of the tidal factor. A broad general picture is the aim, and it is not expected that all areas will be studied intensively. Factors other than tidal factors will clearly be involved, but since air exposure (and this includes water loss, exposure to high temperatures, exposure to salinity changes) is a causal factor and is primarily due to tidal phenomena it has been selected for primary investigation. Information is also required as to the number and location of critical levels on the different types of shore, and this is a further aspect that will be investigated.

## GEOLOGY

The present study concerns Stanmore Bay, which lies between Red Beach and Manly on the north coast of the Whangaparoa Peninsula at its proximal end. It is about 25 miles north of Auckland and is just within the Hauraki Gulf (Fig. 1). The sea-water is considerably purer than that on the south side of the peninsula where there is sewage and harbour contamination.

The bay is backed by high cliffs which in the centre terminate in a narrow sand-dune shelf, but which at both ends come down sheer to the sea. The rock is the soft Waitemata sandstone and erosion is progressing

continually at the two ends of the bay. At the northern end there is an outcrop of Parnell Grit, which is more resistant to wave action. Here vertical rock faces and dissected platforms are to be found.

On either side of this promontory the soft rock has been worn down to beach level and is continually being covered and uncovered by the beach sand. Because of this the vegetation on this low beach shelf is restricted since sand scour eliminates all but the hardiest plants, especially from mid-tide upwards. Towards low water mark the rock is maintained free of sand and here there is a good covering of vegetation.

The above type of flat shelf is to be found on both sides of the bluff separating Stanmore from the small bay immediately to the northwest, but the latter differs from Stanmore in that there are some big boulders near high water mark. The northwestern end of the small bay terminates in a steep bluff with a wide wave-cut platform and a large cave at the base.

## AREA

The area studied included the flat beach shelf in the centre and northwest of Stanmore Bay, the northwest bluff, and the whole of the small bay to the northwest leading up to Red Beach. The cave in the second bluff did not form a part of this investigation.

## THE FAUNA AND FLORA

On the sea shore, especially on rocky coasts, it is impossible to consider the plants and animals independently. In this particular area the dominant animals have been included but secondary species have been neglected. The communities recognised belong to four

<sup>1</sup>University College, Auckland. Manuscript received March 29, 1949. (Read at Science Congress, Wellington, New Zealand, May 23, 1947.)

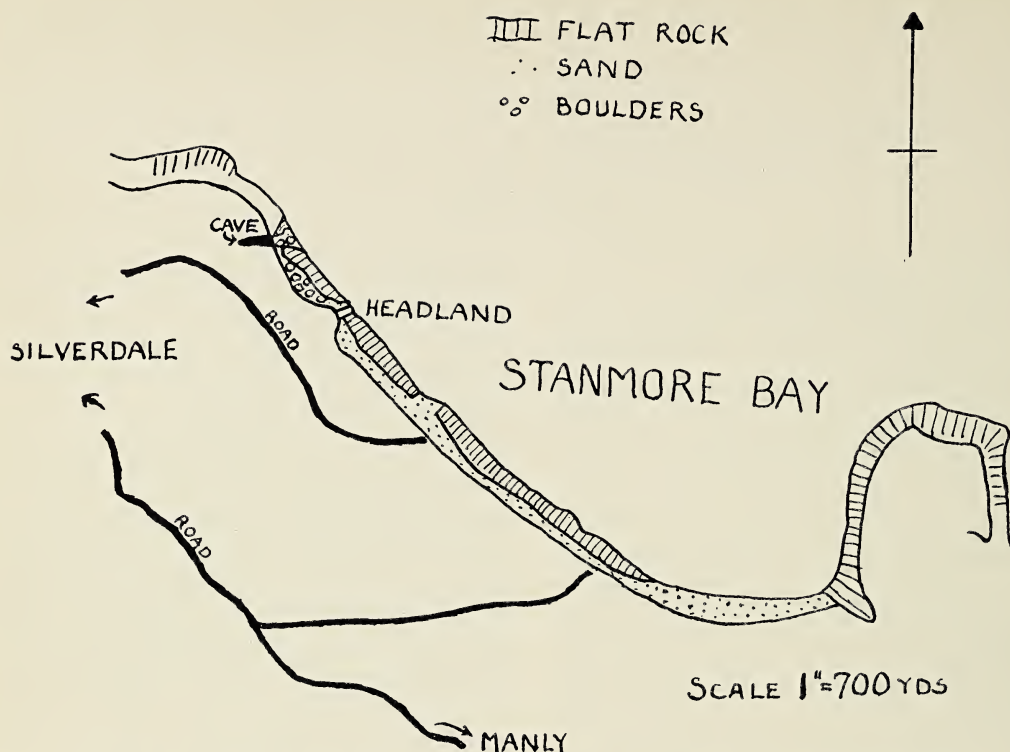


FIG. 1. Sketch map of part of the Wangaparoa Peninsula at the proximal end.

major formations which, as Stephenson (1939) suggests, have a very wide distribution. These four major formations are:

- A. *Littorina* formation of the upper littoral.
- B. Barnacle formation of the mid littoral.
- C. Mixed algal formation of the lower littoral. This is a new nomenclature but the belt is to be found in many parts of the world. In Stephenson's work it would include part of the lower barnacle zone and part of the sublittoral fringe.
- D. Sublittoral brown kelp formation (sublittoral fringe of Stephenson). It seems better to recognise at this level at least two formations, one dominated by large brown seaweeds (kelps) belonging to the Laminariales or Fucales, and one dominated by green, red, and brown algae. The former is to be found in colder waters and the latter

in warmer waters where coral will grow.

The following is a description of the various zones as they occur at Stanmore (see Fig. 2).

#### *Littorina* Formation

##### 1. *Melaraphe*-*Lichina* association

The dominant species are *Melaraphe oliveri* and *M. cincta*, which are closely allied to *Littorina*, and the maritime lichen *Lichina pygmaea*. The *Lichina* occurs in patches and there is no complete vegetation cover. A number of other species are to be found in the association. *Bostrychia arbuscula* occurs in the lower part of the zone; in the upper part a blackish belt of *Brachytrichia quoyi*, *Hydrocoleus lyngbyaceus*, and *Entophysis granulosa* covers the rocks and boulders. Still higher on the boulders *Calothrix scopulorum* and *Enteromorpha procera* f. *novae-zelandiae* are to be found. This association is not to



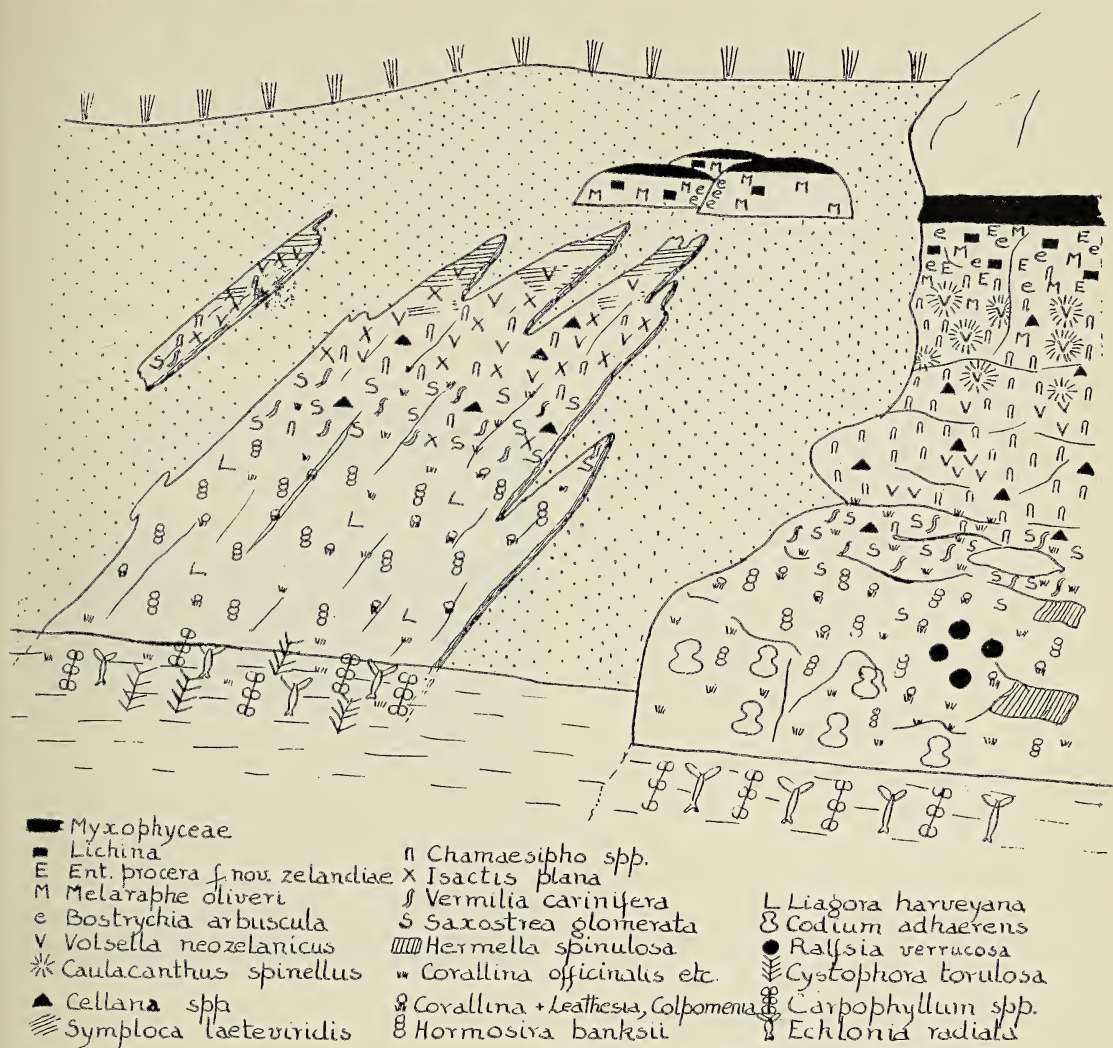


FIG. 2. Diagram of zonation on flat rock (left) and bluffs (right) at Stanmore Bay.

be found on the flat shelf of the beach as the shelf is usually covered by sand at the level at which it would occur. It is therefore restricted to the bluffs and to the large boulders in the small bay. The lower part of the zone is characterised by the presence of the two barnacles, *Chamaesipho brunnea* and *C. columna*, the latter being more abundant than the former.

Where the rock is overhanging, so that there is more shade and presumably less evaporation, one may find *Rhizoclonium tortuosum*, *Enteromorpha salina*, and *Wittrockiella*

sp.<sup>2</sup> Here too may be found tufts of *Caulacanthus spinellus* and one or two outliers of *Volsella*, the mussel of the belt immediately below.

#### Barnacle Formation

#### 2. *Chamaesipho*-*Volsella*-(*Apophloea*) association

In this area the dominants are *Chamaesipho columna* and *Volsella neozelandicus* but in other places it is evident that the red alga,

<sup>2</sup>This is a new species of an interesting genus. A description will be published separately.

*Apophloeia sinclairii*, is normally co-dominant. The red alga is to be found in this belt at Stanmore, but not in abundance. In order areas also there is usually some development of *Chamaesipho brunnea* but the species is not common in this locality. The species of *Chamaesipho* extend rather higher than does the *Volsella*. The associated species vary with the physiography but among the mollusks one may find both species of limpet, *Cellana ornata* and *C. radians*. On the flat beach rock one finds black patches of *Isactis plana*, *Symploca laeteviridis*, *Microcoleus tenerimus*, *Calothrix scopulorum*, and red patches of what appears to be *Hildenbrandtia* sp. *Corallina* occurs in shallow pools, though if the pools are sandy it is replaced by *Pylaiella* (*Bachelotia*) *novae-zelandiae* (Chapman and Ambler, in press). In places the *Isactis* and *Symploca* are sufficiently abundant to form a distinct fasciation: the former does not extend to quite the same height as the *Volsella*. *Symploca* tends to replace the other alga in this area.

At the bluffs, where there are vertical rock faces, other species are to be found. These include a more frequent appearance of the large barnacle *Elminius plicatus*, the limpets *Cellana ornata* and *C. radians*, and the following algae: *Caulacanthus spinellus*, *Gelidium pusillum* G. *caulacanthum*, *Bostrychia arbuscula*, *Rhizoclonium bookeri*, and *Poly-siphonia rudis*. It is here also that occasional patches of *Apophloeia* may be seen.

The *Caulacanthus* is interesting because each colony appears to have started within a group of mussels and to have radiated out from that centre, so that each group of mussels becomes surrounded by a ring of the algal felt.

### 3. *Vermilia*-*Saxostrea* association

Both the species (*Vermilia carinifera* and *Saxostrea glomerata*) occupy a well-marked zone. The rock oyster is rather more abundant than the serpulid worm and also extends

to a higher level on the shore, so that it overlaps into the association described above. Likewise the *Vermilia* often descends somewhat lower on the shore than the oyster. An alternative treatment would be to separate these animals into two independent communities but in view of the overlap they are here retained as one association. This community is absent from the flat shelf and is only to be found on the more resistant rocks of the

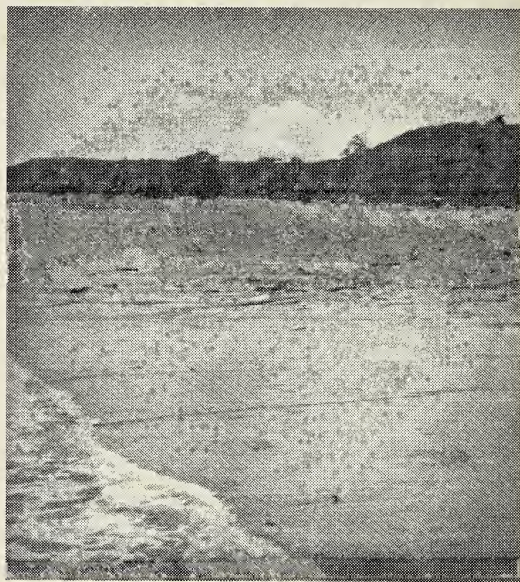


FIG. 3. The flat shelving beach at Stanmore Bay.

bluffs. The associated species are not numerous and include *Chamaesipho columna*, *Elminius plicatus*, *Caulacanthus spinellus*, *Gelidium pusillum*, *Peyssonelia* sp., *Corallina officinalis* (basal portion only), and *Lyngbya confervoides*.

At the bluff the lower part of this zone is further characterised by a considerable local development of *Ralfsia verrucosa* and also of the worm *Hermella spinulosa*. Scattered through both the *Chamaesipho*-*Volsella* and *Vermilia*-*Saxostrea* associations one may find the mollusks *Lunella smaragda* and *Lepsiella scobina*.



*Lower Littoral Mixed Algal Formation*4. *Hormosira*–*Corallina* association

This association is extremely well-marked both on the flat rock shelf and also on the more varied rock faces of the bluffs. *Hormosira*, *Corallina officinalis*, and *Codium adhaerens* are present at all seasons, but *Leathesia* and *Colpomenia* are mainly to be found in the summer months. *Corallina* extends up beyond the normal limit of this association, but only where there are cracks or shallow depressions that remain moist when the tide is below the upper limit of the association as a whole.

Since this association is near low water mark, conditions are favourable for a number of species and the flora is relatively rich. It also includes the serpulid *Vermilia* and *Hermella spinulosa*. The algal species are as follows:

- Leathesia difformis* (spring and summer) (ab.)
- Colpomenia sinuosa* (spring and summer) (ab.)
- Microdictyon* sp. (see footnote 2, p. 65.) (o.)
- Laurencia thyrsoifolia* (f.)
- Laurencia botryoclada* (o.)
- Laurencia pinnatifida* (o.)
- Caulacanthus spinellus* (l.f.)
- Jania* sp. (f.)
- Rhizoclonium tortuosum* (r.)
- Cystophora torulosa* (r.)
- Dictyota dichotoma* (r.)
- Dictyota ocellata* (r.)
- Aphanocladia delicatula* (l. ab.)
- Splachnidium rugosum* (r.)
- Gigartina chapmanii* (o.)
- Liagora harveyana* (f.)
- (summer only)
- Calothrix pilosa* (l.)

ab. = abundant; f. = frequent; o. = occasional; r. = rare; l. = locally.

*Sublittoral Brown Kelp Formation*5. *Carpophyllum*–*Ecklonia* association

This was not studied in any detail but the upper limit of the association was established. The dominant species are *Carpophyllum maschalocarpum*, *C. plumosum*, and *Ecklonia radiata*.

## FRESHWATER SEEPAGE COMMUNITY

There are one or two places where there is a steady trickle of fresh water over the surface of the rocks near high water mark. In such places a characteristic vegetation has developed dominated by *Enteromorpha compressa* f. *subsimplex*. A number of species are associated with the dominant and they include *Rhizoclonium hieroglyphicum* (f.), *R. riparium* (f.), *Calothrix scopulorum*, *Nodularia harveyana*, *Microcoleus acutissimus*, and *Rivularia polyotis*.<sup>3</sup>

## TIDAL PHENOMENA

A temporary tide pole was established at Stanmore and several successive readings of high tides were noted on this pole or on the adjacent vertical rocks. These marks were subsequently levelled with a theodolite and at the same time a series of positions marking the upper and lower limits of the major communities was levelled. The levelled readings of the high tides were then compared with the records from the tide machine in Auckland Harbour, and, after allowance had been made for tides obviously affected by winds, it was found that 5.2 feet on the tide pole corresponded to 8.5 feet on the Auckland Harbour Board datum.

## ASSOCIATION LEVELS

When the levels were examined it was found that in the case of the mussel and the *Chamaesipho* species the upper limits on the flat beach rock were lower than those on the vertical faces of the bluff rocks. This eleva-

<sup>3</sup>The author is grateful to Dr. F. Drouet for identification of some of the Myxophyceae.

tion at the bluffs can be accounted for on the basis of splash action. In other words there is a definite splash zone at the bluffs of nearly 1 foot (see Table 1). Other species are apparently not so affected in this way.

One very interesting point that emerged from this survey was that in general there is a far wider range of values for the upper limits of species than for lower limits, and it therefore appears that the lower limits are more rigidly controlled than the upper limits.

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TABLE 1  
VERTICAL RANGE OF SPECIES AT STANMORE BAY

SPECIES	LIMITS	AVERAGE*	HEIGHT DUE TO WAVE ACTION*	RANGE*
<i>Volsella neozelanicus</i> . . .	upper	9.49	10.19	8.2 -11.78
	lower	6.58	.....	6.34- 6.76
<i>Chamaesipho</i> spp. . . .	upper	9.39	10.24	8.2 -11.78
	lower	6.71	.....	6.66- 6.76
<i>Saxostrea glomerata</i> . . . .	upper	7.44	.....	6.76- 8.13
	lower	5.56	.....	.....
<i>Vermilia carinifera</i> . . . .	upper	6.26	.....	5.39- 7.07
	lower	5.56	.....	.....
<i>Corallina, Hormosira, Leathesia</i>	upper	5.19	.....	4.8 - 6.27
<i>Elminius plicatus</i> . . . . .	upper	8.59	.....	.....
<i>Liagora harveyana</i> . . . . .	upper	4.29	.....	.....
<i>Codium adhaerens</i> . . . . .	upper	5.29	.....	5.14- 5.47
<i>Carpophyllum</i> spp. . . . .	upper	2.53	.....	2.24- 2.82
<i>Cystophora torulosa</i> . . . . .	upper	4.04	.....	.....
<i>Ecklonia radiata</i> . . . . .	upper	2.07	.....	2.24- 2.29

\*Admiralty datum. All measurements in feet.



## NOTES

### The Crab Parasite *Sacculina* in the Fiji Islands

On March 18, 1949, through the kind help of Mr. Harold Gatty at Suva, I obtained the opportunity to collect corals on the reefs near Tomberua Island on the east side of Viti Levu, the main island of the Fiji Group. In addition to other material I found two specimens of the crab *Xantho exaratus* (H. Milne Edwards) which were infested with the parasite *Sacculina leptodiae* Guérin-Ganivet.

The parasites have the broadly oval shape which seems to be characteristic of the specimens living on *Xantho exaratus* (cf. Fig. 1a-d in Boschma, H., *Zool. Medea*. 30(3): 49-71, 21 figs., 1948); their greater diameter is approximately 6 and 5 mm. They are attached to hosts which have a carapace breadth of 13.5 and 11.5 mm. respectively.

In shape and size the excrescences of the external cuticle of the mantle do not differ from those of specimens found on the same crab from other localities. In the larger specimen these excrescences have a length of 35 to 45  $\mu$  (Fig. 1, upper row); in the smaller specimen they have a length of 30 to 40  $\mu$  (Fig. 1, lower row).

*Sacculina leptodiae* was described by Guérin-Ganivet (*Trav. Sci. Lab. Zool. et Physiol. Marit. Concarneau* 3(7): 1-97, 1911). His material came from the Gulf of Aden and from the Comoro Islands in the Mozambique Channel. Other specimens on *Xantho exaratus* are known from Zanzibar, the Red Sea, and the Andaman Islands. In the East Indies the parasite is of common

occurrence on the crabs *Thalamita simpsoni* A. Milne Edwards and *Pseudozinus caystrus* Adams & White (Boschma, loc. cit.). The occurrence of the parasite in the Fiji Islands considerably extends its known range of distribution.

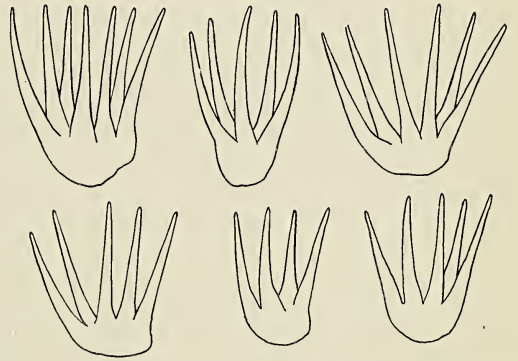


FIG. 1. *Sacculina leptodiae* Guérin-Ganivet: specimens from Tomberua Island, Fiji. Excrescences of the external cuticle of the larger specimen (upper row) and of the smaller specimen (lower row).  $\times 530$ .

Until now there was only one record of a rhizocephalan parasite in the Fiji Islands, viz., that of specimens of the genus *Thompsonia* on the snapping shrimp *Alpheus malleodigitus* (Bate), obtained by the "Challenger" Expedition on the reef of Levuka, Ovalau Island, east of Viti Levu (Bate, C. S., *Rept Sci. Results Voyage H. M. S. Challenger*, *Zool.* 24. xc + 942 pp., xv + 76 figs., 157 pls.).—H. Boschma, *Rijksmuseum van Natuurlijke Historie, Leiden*.

## On the Supposed Occurrence in New Zealand of the North Pacific Fish Genus *Sebastodes*<sup>1</sup>

While attending the Seventh Pacific Science Congress in New Zealand I presented a paper on what I proposed to call the "antitropical" elements in the marine faunas, using this generalized term to include what I have for some time been calling "pantemperate" as well as what has long passed under the rather misleading term "bipolar." Many patterns of antitropical ranges were indicated. My interest was consequently excited when, shortly afterward, I encountered two specimens in the Dominion Museum at Wellington that were labelled *Sebastodes maccullochi* Phillipps. If the genus *Sebastodes* should be found to occur also in New Zealand, we would have another example of antitropicality of a rather unique type. This large genus, except for one species or species group that ranges from Peru to South Africa, is strictly confined to the two sides of the North Pacific.

An examination of the somewhat complicated evidence indicates, however, that we do not have a new case of antitropical distribution. The specimens that I examined are referable to a well-known New Zealand species that cannot be included in *Sebastodes*. Nor do they represent the species that was described as *Sebastodes maccullochi* by Phillipps (*New Zeal. Inst., Trans. and Proc.* 58: 127-128, pl. 3, fig. 2, 1927). Nor is that nominal species properly referred to *Sebastodes*. The type description and figure call for its reference to the genus *Helicolenus*. Although that genus is essentially pantemperate, a new example of antitropical distribution is not provided since *Helicolenus percoides* (Richardson) has long been recognized as a member of the faunas of New Zealand and Australia.

All characters evident in the description and figure of "*Sebastodes maccullochi*" agree

with *Helicolenus* as currently defined, for instance by Barnhart and Hubbs (*Calif. Univ. Scripps Inst. Oceanography, Bul.* 5: 373-377, 385, 1946). There are only 12 dorsal spines (13, rarely 14, in *Sebastodes*) and 5 anal soft-rays (typically 6 to 9 in *Sebastodes*). The dorsal fin begins well backward on the nape, far behind the eye, and is not very deeply notched between the spinous and soft-rayed parts. The spines are not markedly elongated. The pectoral fin has a relatively narrow base, for the lower rays are not procurrent. Some of the upper pectoral rays are branched (not simple as in *Pontinus*). The body is completely scaled and the head is largely scaled. The lateral line is complete. In the absence of contrary evidence it can be assumed that the palatines are toothed. The head is relatively smooth, without deep caverns and high ridges, and with only moderately developed spines. The suborbital keel, developed anteriorly, is spineless. The border of the orbit is smooth.

Though a final identification should await thorough comparisons of specimens, it may be suggested that *Sebastodes maccullochi* Phillipps is probably a synonym of *Helicolenus percoides* (Richardson), the only species of *Helicolenus* now recognized from New Zealand. The type figure, from a photograph, certainly resembles very closely the drawing of *H. percoides* published by Waite (*South Austral. Mus., Rec.* 2: 162, fig. 266, 1921). Synonymies of that species have been given by Waite and by Phillipps (*New Zeal. Mar. Dept. Fish Bull.* 1: 53, 1927).

I wish to thank Mr. W. J. Phillipps of the Dominion Museum in Wellington for assistance and numerous courtesies.—*Carl L. Hubbs, Scripps Institution of Oceanography (University of California), La Jolla, California.*

<sup>1</sup>Contributions from the Scripps Institution of Oceanography, New Series No. 447.



## News Notes

Dr. Hans Pettersson, Director of the Oceanographic Institute, Göteborg, Sweden, and leader, on the "Albatross," of the Swedish Deep-Sea Expedition of 1947-48, returned to Honolulu early in December, 1949, to give a series of lectures under the auspices of the University of Hawaii, the Hawaiian Academy of Science, the Hawaii Chapter of the Society of the Sigma Xi, the McNerny Foundation, and the Hawaiian Botanical Society.

Information has reached us through the Interim Secretariat of the Pacific Science Council that the University of British Columbia, in cooperation with the Defense Research Board and the Fisheries Research Board, is establishing an institute of oceanography. The committee in charge of organizing the institute consists of: Dr. W. A. Clemens, Dr. F. H. Sanders, Dr. J. G. Hooley, Dean H. F. Angus, Dr. G. M. Shrum, and President MacKenzie (ex officio). The institute will undertake graduate teaching and research in physical, chemical, and biological oceanography. The teaching staff will include Mr. W. M. Cameron, Dr. G. L. Pickard, and Dr. J. P. Tully.

We are further informed by the Interim Secretariat that two modern seismographs have been installed in the South Pacific Area—one in Western Samoa, one on South Island, New Zealand. Two others are ready for installation on North Island, New Zealand.

The following publications of the Natural Resources Section and of the Economic and Scientific Section, General Headquarters, Supreme Commander for the Allied Powers, have been received. Each report includes a list of all the reports previously published, their distribution, and rules for obtaining them.

### NATURAL RESOURCES SECTION:

*Systematic List of Economic Plants in Japan.* [By H. Takeda.] Report No. 121. 83 pp.

*Pearl Culture in Japan.* [By A. R. Cahn.] Report No. 122. 91 pp., 22 figs., 7 tables.

*High-Yield Pulping Processes in Japan.* [By Harold R. Murdock.] Report No. 123. 39 pp., 16 figs., 8 tables.

### ECONOMIC AND SCIENTIFIC SECTION:

*Natural Science Research in Leading Japanese Universities, Part I.* Report No. 16. 26 pp., 6 tables.

*Abstracting Program: Japanese Scientific Journals Covering the Period December 1941-1948.* (Progress Report.) Report No. 19. 13 pp.

*Scientific and Technological Societies of Japan, Part II.* Report No. 20. 185 pp.

A new map of the island of Saipan and an accompanying *Preliminary Gazetteer of Geographic Names for Saipan* have been prepared by the Geological Surveys Branch, Intelligence Division, Office of the Engineer, General Headquarters, Far East Command.





# PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



IN THIS ISSUE: Ostergaard—*Spawning and Development of Marine Gastropods* • Yasumatsu—*Vespoidea of Micronesia* • Tokida and Inaba—*Antithamnion and Related Algae* • Haneda—*Harpodon nehereus, a Non-luminous Fish* • Viette—*Noc-tuidae from New Caledonia and New Hebrides* • Asano—*Upper Cretaceous Foraminifera* • NOTES

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MAY 17 1950





# Spawning and Development of Some Hawaiian Marine Gastropods<sup>1</sup>

JENS MATHIAS OSTERGAARD<sup>2</sup>

MANY PERSONS, at various marine biological stations situated throughout the world, have investigated the spawning habits and larval development of marine gastropods. Some of the recorded observations date back to the middle part of the last century or earlier. Various methods have been employed to obtain the materials for study, but always the effort put forth has been well rewarded, for the field is exceedingly rich. It is noteworthy that the study of plankton alone has been able to throw much light on the metamorphosis of the larvae of many species. This is a field of investigation that has an economic as well as an academic value, inasmuch as these minute planktonic larvae make a considerable contribution to the food supply of larger organisms, which in turn may serve as food for fishes that are of direct economic importance to man.

The investigations recorded here are the first to be published from this area of the Pacific. All the studies were done at the Marine Biological Laboratory of the University of Hawaii during the years 1920–1925, since which time nothing has been added. There are several reasons for this delay, the main one being the difficulty of publication. This required, among other things, much painstaking labor by a skilled person to adapt the many illustrations for reproduction.

Many illustrations were required to clarify the text and to enable the reader to compare the corresponding stages of species of the same genus. All the figures were drawn in

lead pencil by the author from observation under low power of the compound microscope. A micrometer scale was used so that measurements in fractions of millimeters could be made readily.

All the species investigated were obtained in water not over 3 meters in depth, and most of the egg structures were deposited in the laboratory by isolated animals. When the spawns were obtained from the reefs, or elsewhere, careful checks had been made to ascertain their identity, which in most cases was later verified. No record of any species whose generic position was unknown has been included. Hence, discussion of a considerable number of additional species of the Nudibranchiata, whose systematic position has not yet been fully determined, awaits later publication.

No histological sections of embryos and larvae were made, all notes being from external observations. It will be noted that the ova of the various groups of gastropod mollusks discussed here were of the telolecithal type with holoblastic cleavage, of which the first two divisions were almost always equal, while the third division resulted in some blastomeres of minute size and with a small amount of yolk and other larger ones with much yolk. A trochophore stage of very short duration has been observed in some species, while a long veliger stage seems to be present in all. In no case has a metamorphosis from the veliger larva to the adult form been observed, nor even started, although a record was obtained of 21 days of free-swimming existence.

Included in this publication are the results of the study of the development of 41 species which are placed in 28 genera belonging to

<sup>1</sup>Contribution No. 2, Hawaii Marine Laboratory.

<sup>2</sup>Department of Zoology and Entomology, University of Hawaii. (Retired.) Manuscript received May, 1949.

25 families of 3 orders. A key is furnished to aid in the identification of the spawn.

Material collected and in the author's possession consists of egg structures preserved in formaldehyde and balsam mounts of cleavage stages and veliger shells on slides.

Acknowledgments: The author feels indebted to a number of persons for their aid and encouragement in the present undertaking. Thanks are due Dr. Charles H. Edmondson for his fine cooperation in securing specimens of mollusks from which spawn were obtained. I also wish to thank Mr. Otto Degener for having rendered much assistance in procuring living specimens of opisthobranchiate mollusks. I greatly appreciate Dr Robert W. Hiatt's very helpful suggestions and aid in the preparation of the manuscript. Finally, I am greatly indebted to Florence Lambeth for the painstaking skill with which she adapted the drawings for reproduction.

#### KEY TO THE SPAWN OF SOME HAWAIIAN MARINE GASTROPODS

1. Egg structure consisting of distinct, attached capsules with parchment-like walls or a continuing filament . . . . . 2
  - Egg structure otherwise, more or less aberrant . . . . . 23
- 2 (1) Egg structure capsular with compact parchment-like walls . . . . . 3
  - Egg structure consisting of a continuing filament . . . . . 5
- 3 (2) Capsules small, 1.5-4 mm. in length, pale yellow . . . . . 4
  - Capsules large, 8 x 10 mm. to 13 x 15 mm., squarish, flat and baggy, more or less corrugated marginally; attached to rock at basal margin or to one another (*Conus omaria*, p. 90); with elongate slit at distal margin which is closed during incubation. Color pale yellow or pink. . . *Conus*, p. 89.
- 4 (3) Capsules oblong, rounded or pointed; adhering to one another in compact masses. Egg mass covered by foot of animal during incubation. Color pale yellow. . . *Cypraea*, p. 78.
- Capsules elongate, pointed; attached to substratum . . . . . *Mitra*, p. 86.
- 5 (2) Egg structure a cylindrical filament . . . . . 6
  - Egg structure a ribbon or band . . . . . 15
- 6 (5) Filament long, thin and tangled . . . . . 7
  - Filament short, thick and not tangled . . . . . 10
- 7 (6) Filament from 0.5 mm. to 1 mm. in diameter . . . . . 8
  - Filament about 0.25 mm. in diameter, thread-like, comprising many separate threads forming a bundle spread over 4 square cm. Color pale yellow. *Strombus maculatus*, p. 95.
- 8 (7) Filament of great length, about 1 mm. in diameter, adhering in a compact mass, attached to underside of rocks and spread over an area of 25 square cm. Color pale yellow when freshly laid, brown when embryos are near hatching. . . . . *Tethys grandis* and *T. bipes*, pp. 98, 99.
- Filament not of great length, occupying an area from 2 to 4 square cm. Color pale yellow. . . . . 9
- 9 (8) Filament compactly tangled and attached to substratum . . . . . *Clava obeliscus*, p. 95.
- Filament loosely looped or tangled and festooned on algae . *Tethys elongata*, p. 100, and *Notarchus striatus*, p. 101.
- 10 (6) Filament with ova transversely arranged in loops within, and visible to the unaided eye . . 11
- Filament without transversely arranged ova . . . . . 12



- 11 (10) Filament large, forming an elliptical loop. Length 18 cm., diameter 4 mm. Color white. . . . *Pleurobranchus* sp., p. 107.  
Filament small, forming a circular loop. Length 3 cm., diameter 1 mm. . *Bulla* sp., p. 103.
- 12 (10) Filament slender and tapering to an acute point at the extremities . . . . . 13  
Filament thick with obtuse or blunt extremities with or without spiral twists . . . . . 14
- 13 (12) Filament forming one volution without loops. Length 19 mm., diameter 1 mm. Color white. . . . .  
 . . . . *Placobranchus* sp., p. 107.  
Filament with a few irregular loops. Length 25 mm., diameter 0.5 mm. Color white. . . . . *Elysia* sp., p. 108.
- 14 (12) Filament with one or two turns, flatly arranged. Length from 2.5 to 4 cm. Color white. . . . .  
 . . . . *Morula dumosa*, p. 96, and *Haminoea crocata*, p. 104.  
Filament with three and a half spiral turns, with one end attached to a gelatinous base or to the substratum. Length 35 mm., diameter 3 mm. Color white. . . . .  
 . *Bullina scabra solida*, p. 103.
- 15 (5) Ribbon attached by one edge or by a basal support to substratum . . . . . 16  
Ribbon attached flatly to substratum . . . . . 22
- 16 (15) Ribbon a much-folded mass attached by a basal support to substratum about 2.5 cm. in height and 1.5 cm. in width. Color white. . . . .  
 . *Hydatina amplustre*, p. 102, and *H. physis*, p. 102.  
Ribbon attached by one edge to substratum . . . . . 17
- 17 (16) Ribbon very large and intensely folded, forming three or four circularly wound volutions which measure about 13 cm. across. Color pink. . . . .  
 . *Umbraculum sinicum*, p. 105.  
Ribbon small and with only slight folds or none . . . . . 18
- 18 (17) Ribbon rising vertically from margin of attachment . . . . . 19  
Ribbon sloping outward from centrally placed margin of attachment . . . . . 21
- 19 (18) Ribbon of one volution; extremely small white band, about 4 mm. in length . . . . .  
 . . . . *Glossodoris* sp., p. 109.  
Ribbon of 2 to 3 volutions, 2 to 3 cm. across the mass . . . . . 20
- 20 (19) Ribbon bright scarlet or deep orange, forming two volutions, about 14 cm. long and 6 mm. wide . . . . .  
 . . . . *Hexabranchus* sp., p. 109.  
Ribbon bright yellow, forming 3 volutions, about 11 cm. long and 4 mm. wide . . . . .  
 . . . . *Cryptodoris* sp., p. 109.
- 21 (18) Ribbon with one volution. Diameter of entire structure about 1 cm. Color bright yellow. . . *Aeolidia* sp., p. 110.  
Ribbon with several irregular volutions, 7 mm. wide. Color white. . . *Melibe pilosa*, p. 111.
- 22 (15) Ribbon with numerous parallel loops, not overlapping, 0.33 mm. wide. Clear and colorless. . . . .  
 . . *Dolabrifera olivacea*, p. 100.  
Ribbon not looped, forming a half circle, about 3 cm. long, 2 mm. wide. Colorless. . . . .  
 . . . . *Siphonaria normalis amara*, p. 111.
- 23 (1) Egg structure consists of groups of unattached, minute capsules, each containing 1 or 2 ova. The capsules about 0.2 mm. in diameter. . . . .  
 . . . . *Littorina pintado*, p. 97.

- Egg structure not capsular . . . 24
- 24 (23) Egg structure a gelatinous mass . . . . . 25
- Egg structure not a gelatinous mass but orbicular or fan-shaped and of great size. Diameter 15 cm., thickness about 2 mm. Ova grouped together in masses of about 50, visible to the unaided eye and arranged in transverse rows of about 50. Color pale yellow. . . *Tonna perdix*, p. 96.
- 25 (24) Egg mass consisting of a globular, soft, clear gelatinous matrix about 18 mm. in diameter in which about a thousand purple-colored ova are imbedded. . . . .
- . . . . *Atys semistriata*, p. 105.
- Egg mass of irregular outline, tough, gelatinous, and pasted flatly to any surface, occupying about 5 square cm. Color lemon yellow. . . . .
- . . . . . *Peronia* sp., p. 112.

## Order PROSOBRANCHIATA

### Family CYPRAEIDAE

#### Genus CYPRAEA

#### *Cypraea carneola* Linnaeus

Figs. 1, 2

On June 8, 1921, a large adult specimen of *Cypraea carneola* was found on the Waikiki reef, off the Marine Biological Laboratory of the University of Hawaii. This species is not of common occurrence in wading depths on the Hawaiian reefs.

The specimen was brought to the laboratory and placed in a trough with running water, and the following night it deposited an egg mass on the enameled surface of a pan in which it was placed. The egg mass consisted of about 1,000 egg capsules which were imbedded in a firm gelatinous substance.

The individual egg capsule, or egg case, is about 4 mm. long and is triangular, with its flattened base attached to the substratum or to another egg capsule. From its base the egg capsule curves slightly to a somewhat obtuse point (Fig. 1*a*). Its firm parchment-like walls are pale yellow and contain, in a clear viscid capsular fluid, an average of 500 ova (Fig. 1*b*).

During the first day the animal remained constantly on its eggs, covering the entire mass with its foot; thereafter, probably due to having been removed several times, it left its "nest" voluntarily and stayed away.

Under the compound microscope the cleavage of the zygote was studied, as were the resulting embryos as far as the free-swimming larval stage.

The ovum is about 0.14 mm. in diameter, and a concentration of cytoplasm containing the nucleus appears as a clear area about one-fifth the diameter of the ovum. This in turn is surrounded by a dark area, while somewhat globular yolk granules constitute the bulk of the ovum (Fig. 1*c*).

Upon examination of the contents of one of the egg cases the morning after they were laid, none of the zygotes was found to have started cleavage. The contents of another egg case, however, opened at 4:00 P.M. of the same day, revealed many in the two-cell stage scattered among those which had not started cleavage.

This is a telolecithal egg with holoblastic, or total, cleavage, the first two divisions being equal, the third unequal. The first cleavage is vertical and passes through the animal and vegetal poles of the zygote, dividing it into two blastomeres of equal size. The animal, or formative, pole is clearly discernible by the position of the nuclei, the nucleus of each daughter cell being directly opposite that of the other, and close to the cleavage plane (Fig. 1*d*).

An hour later, at about 5:00 P.M., the second division began to take place; and in the



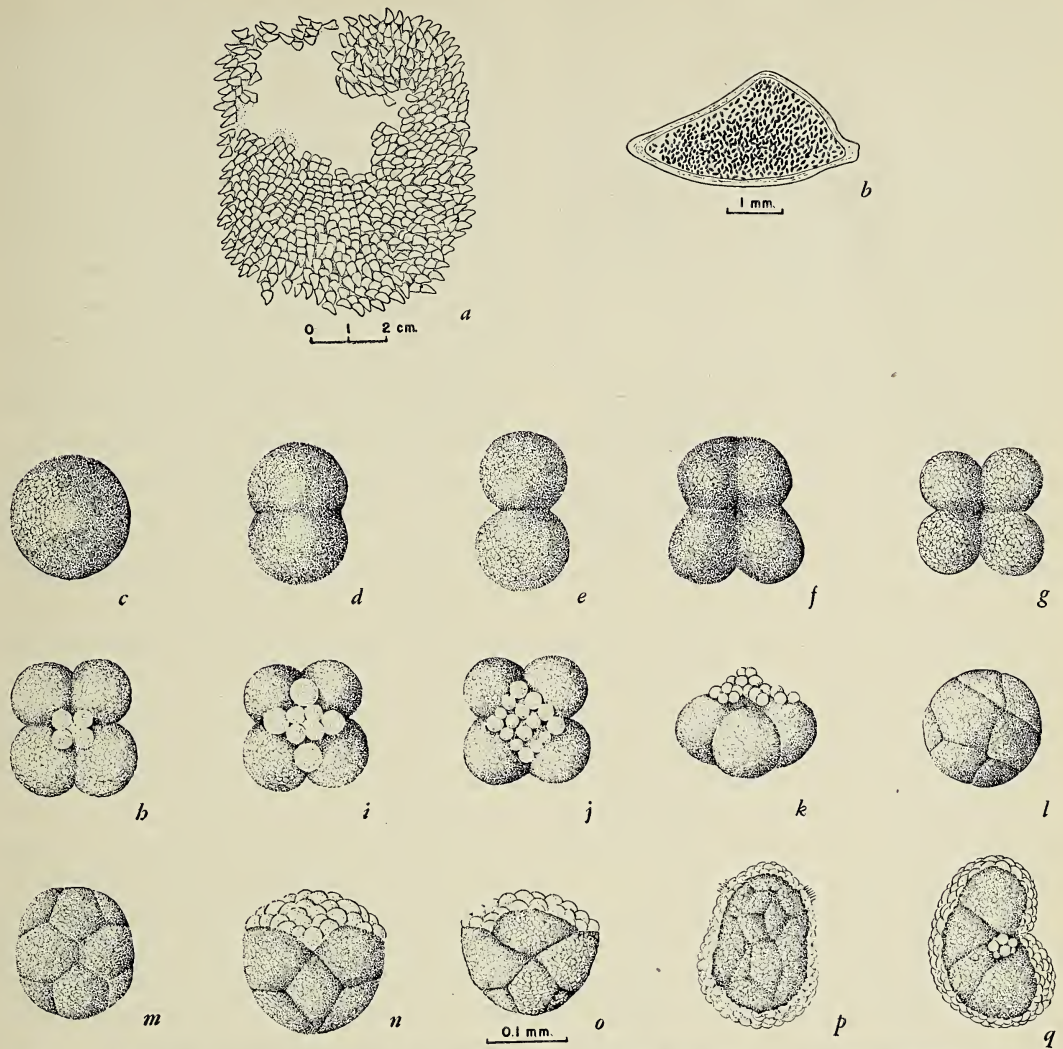


FIG. 1. *Cypraea carneola* Linnaeus. *a*, Egg mass; *b*, capsule enlarged; *c*–*n*, cleavage stages; *o*, blastula stage; *p*, trochophore stage; *q*, gastrula stage.

course of about  $\frac{1}{2}$  hour, nearly all the embryos in the two-cell stage had completely divided into four blastomeres of equal size, symmetrically arranged, and joined together by their inner surfaces. Like the first cleavage, this was vertical and at a right angle to the first. The nuclei of the blastomeres were grouped together about the animal pole. Following each of the preceding cleavages, a contraction and rounding off of the blastomeres occurred which resulted in their being joined at the cleavage planes by a compar-

atively small area (Fig. 1*g, h*).  
By 11:00 P.M., another division had taken place in the horizontal plane and at right angle to the two preceding cleavages forming four micromeres and four macromeres (Fig. 1*b*).  
At about the same time some embryos had undergone an additional division of the macromeres, thus producing four more micromeres, arranged outside of the others and located in the line of division between the macromeres. The cells of this division were

about twice the volume of the preceding (Fig. 1*i*).

By the following noon, July 10, the micromeres in many of the embryos had increased to 16 in number and, in some instances, they were arranged in orderly rows of four at the animal pole. These cells did not differ much in size; the larger ones were at the outer angles and were, on an average, a little smaller than the first four micromeres. This result had apparently come about through further divisions of the eight micromeres observed in the preceding stage (Fig. 1*j*).

At this time in some of the embryos an additional division of a number of the micromeres had resulted in a crowding together and a piling up into a pointed dome of these small cells at the animal pole (Fig. 1*k*).

At 10:00 P.M., the same day, a marked change had taken place in the appearance of the embryos. An equal division of the macromeres had occurred, making them now eight in number; furthermore, the rounded surfaces of these cells, which had stood out so conspicuously, were now contracted and flattened, giving the whole mass a rather globular form again (Fig. 1*l, m*).

Owing to the thickness of the egg capsule, it was not possible to see the minute structures of the embryos without tearing open the capsule and examining the embryos in water. Being thus placed in unnatural environments, their life was usually short and their development retarded. For this reason, the time normally required for the successive steps of development cannot be correctly indicated.

At the time the micromeres became contracted and rounded off peripherally, the micromeres also pulled toward the center, crowded together, and thus, aided by their increased number, helped to restore the embryo to its former globular form. Viewed from the equator the embryo now resembled a basket full of eggs. This stage was observed July 11, at 3:00 P.M. (Fig. 1*n*).

Twenty-four hours later the embryo had become compressed at the poles and had lost its spherical form. In some, 12 macromeres could be seen, a division of the row distal of the vegetal pole having taken place. The micromeres, increasing in number, occupied a larger area of the surface and extended laterally so as to form an obtuse angle with the macromeres. The beginning of movement of the embryo takes place at this stage although cilia cannot yet be seen (Fig. 1*o*).

The following morning, July 13, an elongated form of the embryo had succeeded the former compressed one, the elongation having occurred along the equatorial plane. The micromeres, by their greatly increased number, now extended over almost the whole of the embryo, leaving but a small area of the macromeres uncovered. This was the blastula stage. The body was slightly tapered at the anterior end, where there was a small tuft of short cilia on each side. By means of these cilia the embryo was able to turn over and move backward and forward. This was the trochophore stage (Fig. 1*p*).

Twenty-four hours later, July 14, a gastrula was formed, partly by epiboly and partly by invagination of the macromeres. A constriction near the point corresponding to the vegetal pole of the ovum indicated the position of the blastopore. The micromeres, which were transparent, had become flattened and formed a layer of nearly equal thickness around the macromeres, which appeared as an inner dark mass. The archenteron appeared as a narrow fissure extending through the clear ectodermal layer and into the large yolk-laden endodermal cells. At the inner end of the archenteron, against the endodermal cells, a group of small, clear cells was seen which were probably mesodermal. The length of the embryo at this age was 0.16 mm. (Fig. 1*q*).

An important change took place in the next 24 hours. Two large, ciliated lateral lobes and a smaller median lobe with shorter



cilia developed from the ectoderm at the anterior end of the body. Directly posterior to each lateral lobe there was a clear, rounded protuberance, probably of ectodermal origin. The foot, also developed from the ectoderm, appeared as a bulky process on the ventral side, posterior to the ciliated lobes. Under it, near its base, was a short, pointed operculum, which on its inner surface was longitudinally convex and laterally concave. Also the shell had begun to form around the posterior part of the body, originating at a postero-dorsal point where it was attached to the body. Laterally and anteriorly the shell projected far out. The endodermal cells had become much distorted and had lost their symmetrical arrangement, yet retained their great size (Fig. 2*a, b, c*).

On July 17, 2 days after the above-described stage was observed, the opening of another capsule revealed larvae with well-developed shells and with an operculum as previously observed, except that it was much larger and extended beyond the foot laterally and anteriorly. Distinct eyes and otocysts were present at this stage as well as a bilobed ciliated velum, the oral lobes. This was the veliger stage, typical of the gastropod larva (Fig. 2*d, e*). Length of the shell at this stage was 0.20 mm.

After this stage changes in the embryo took place more slowly and no new phases occurred. Some of the existing features merely became more pronounced until the free-swimming stage was attained.

By July 23, after 14 days of incubation, the larvae began to escape normally from their egg cases. The ciliated oral lobes were well extended, and on the free surface of the foot a large purple area appeared. The operculum had lost much of its curvature and was large and broad, extending well beyond the foot both laterally and distally. The whole shell was pitted with shallow depressions and had a slight purplish tinge; a similar tinge was also possessed by the larva

(Fig. 2*f, g, h*). At hatching the veliger shell was 0.22 mm. in length (Fig. 2*i, j, k*).

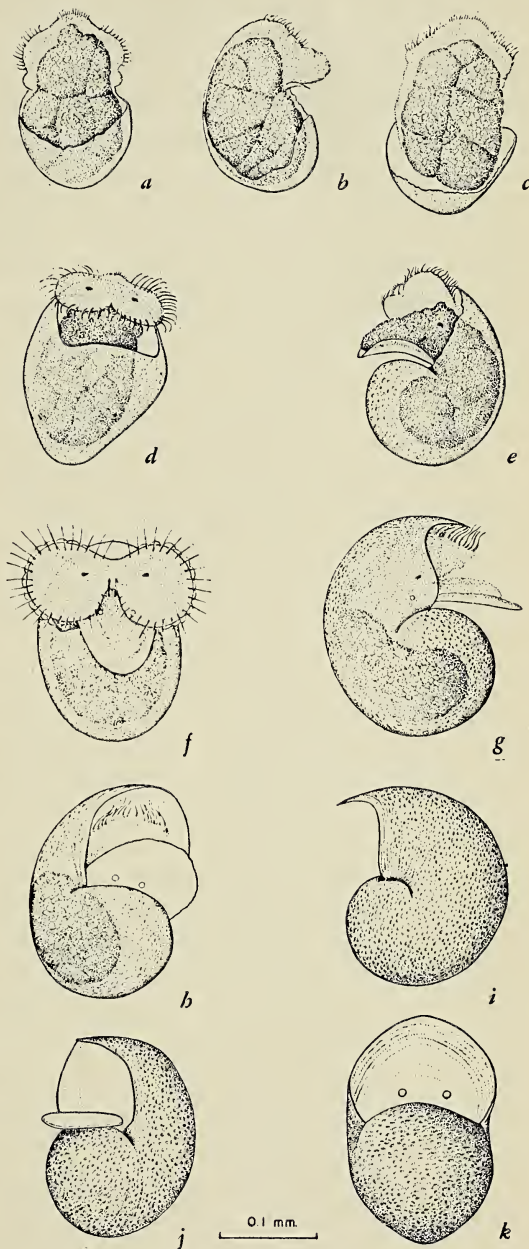


FIG. 2. *Cypraea carneola* Linnaeus. *a-c*, Early stages of shell and operculum: *a*, dorsal, *b*, lateral, *c*, ventral aspects; *d, e*, early veliger stages; *f-h*, free-swimming veliger stage: *f*, ventral, *g*, lateral, *h*, ventrolateral aspects; *i-k*, veliger shell of free-swimming stage showing operculum and otocysts.

*Cypraea isabella* Linnaeus

Fig. 3

During the night of July 21, 1921, a *Cypraea isabella*, which had been brought to the laboratory a few days before, deposited eggs. There were about 1,500 egg cases in three or four layers, held together by a gelatinous matrix, with the egg cases radially arranged. This egg mass, measuring about 24 x 30 mm., was fixed to the surface of a glass in which the animal was kept and was completely covered by the foot of the animal (Fig. 3a). The egg case was somewhat cylindrical in form, about 1.5 mm. long, pale straw color, and contained nearly 200 ova within its thick parchment wall (Fig. 3b).

The development of the embryo and characteristics of the veliger are very similar to those of *Cypraea carneola*. The zygote, which is smaller than that of *C. carneola*, 0.11 mm., undergoes cleavage in the same manner, and shows a corresponding difference in size of macromeres and micromeres, as well as a similar relation of these to one another (Fig. 3c-b). The gastrula stage is formed entirely by epiboly, the micromeres spreading completely around the macromeres. Owing to this condition no invagination is effected and the spherical form of the ovum is retained. This condition was reached after 3 days of incubation (Fig. 3i). In the trochophore stage, which followed, the larva assumed an elongate form and the large endodermal cells took on a distorted appearance. The foot began to develop as did the shell, which could be seen as a rudiment loosely surrounding the posterior part of the body (Fig. 3j, k).

The free-swimming stage was reached after 11 days of incubation, when the larva apparently had developed all the characters of the veliger stage. Between the eyes now appeared an arch of bluish-black pigment, and the foot had a large, broad operculum, as in *C. carneola*; also, as in the latter, the entire shell was covered with small, shallow pits.

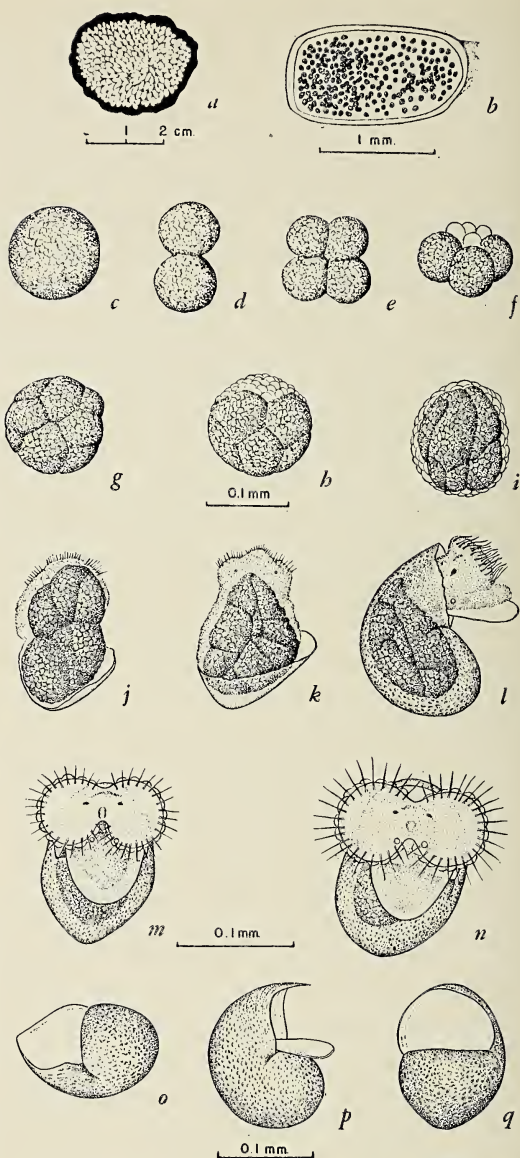


FIG. 3. *Cypraea isabella* Linnaeus. a, Egg mass seen through glass and covered by foot of animal; b, egg capsule enlarged; c-g, cleavage stages; h, blastula; i, gastrula; j, k, trochophore with shell beginning to form: j, ventrolateral aspects, k, ventral aspect; l, m, veliger stage: l, lateral, m, anterior aspects; n, free-swimming veliger; o, p, q, shell of free-swimming veliger showing (p) operculum.

The outer lip of the shell was purplish-brown; the whole shell, which was about 0.15 mm. long, had a pale tinge of that color (Fig. 3l-q).



Some of the larvae which survived until the ninth day of their free-swimming stage gave no evidence of metamorphosis.

### *Cypraea helvola* Linnaeus

Fig. 4

On July 23, 1921, I obtained from a porous rock in shallow water off the laboratory two adult specimens of *Cypraea helvola*, one of which was "sitting" on an egg mass deposited on the rock.

The egg cases, or capsules, numbering about 1,000, were in many layers, imbedded in a gelatinous matrix with their long axes directed radially. The egg mass measured about 13 x 18 mm. (Fig. 4a).

The egg case was somewhat oval, about 2 mm. in length, of a pale straw color like those of *C. carneola* and *C. isabella*, and contained about 200 ova. The capsule walls were thinner than those of the other two and quite transparent.

Figure 4b shows a magnified capsule with embryos in the veliger stage.

When the egg capsules were obtained, they were found to contain embryos in the gastrula stage and were several days along in their development. The gastrulae were quite spherical and had been produced by epiboly, no sign of invagination being perceptible. The transverse measurement of the embryo in this stage was about 0.09 mm. (Fig. 4c).

A little later the gastrula became slightly elongate and a small tuft of minute cilia appeared on each side of the body anteriorly, as in the two preceding species (Fig. 4d).

In the course of 3 days these embryos became free-swimming veliger larvae, which bore a close resemblance to those of *C. carneola* of the same stage, except for being much smaller. As in that species, there was a large purple area on the ventral side of the foot (Fig. 4e, f).

Some of the larvae were kept in jars with standing water for about a week of their free-swimming stage without showing any

perceptible change. Upon hatching they issued from the egg cases simultaneously. The cases were purple, owing to the pigment in the larvae and the transparency of their covers.

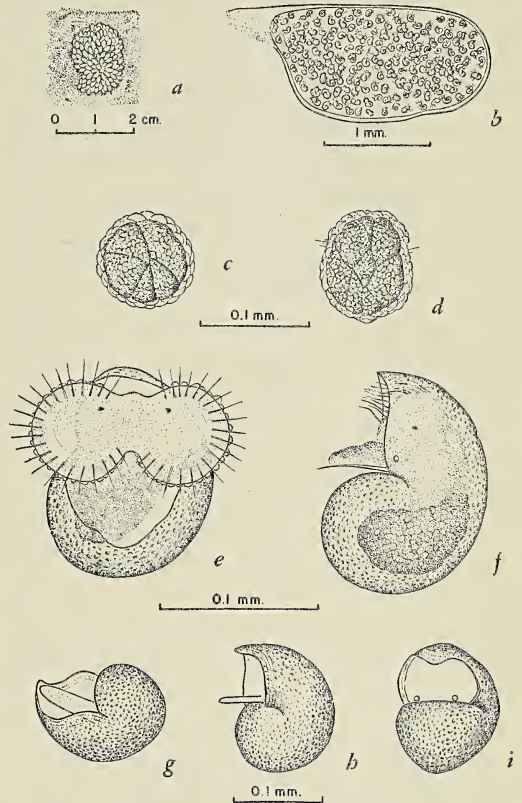


FIG. 4. *Cypraea helvola* Linnaeus. a, Egg mass; b, egg capsule enlarged with embryos in veliger stage; c, d, gastrula stage; e, f, free-swimming veliger stage: e, ventral, and f, lateral aspects; g-i, shell of free-swimming veliger showing operculum and otocysts.

The veliger shell measured 0.14 mm. in length, and in a number of specimens from which the dead animals had been removed by protozoan scavengers, opercula and otocysts remained. The pitted surface of the shell resembled that of the two preceding species (Fig. 4g, h, i).

### *Cypraea caputserpentis* Linnaeus

Fig. 5

The commonest species of the genus in Hawaii is *Cypraea caputserpentis*. It is com-

monly encountered on the shore rocks washed by the surf during high tide. A considerable number of individuals may be seen in a comparatively small area.

The first successful attempt at obtaining the spawn of this species was made on October 26, 1920, when a specimen which was concealing an egg mass under its outspread foot was found on the shore rocks at Diamond Head. The mollusk and egg mass were taken to the laboratory for study.

The egg mass, consisting of about 100 capsules, was somewhat flattened to accommodate the animal "sitting" on it and was spread out suitably for being covered by the foot. The egg mass measured about 1 x 2 cm. through its horizontal diameters. The capsules were somewhat oblong, measured 2 mm. in length, and contained an average of approximately 200 ova.

About 1½ hours after they had been taken off the rocks, the zygotes were in early cleavage stages, having four or more cells. Subsequent investigations seemed to indicate an abnormal condition of development in which

the early embryos assumed a variety of forms, many dying within the capsules. Some of the capsules ruptured in the course of 6 days, liberating embryos long before they had reached the veliger stage; in other capsules the young died. This abnormal condition possibly was caused by a faulty chemical nature of the water.

More satisfactory results were obtained from another egg mass, also taken from shore rocks at Diamond Head. The embryos developed normally to the free-swimming veliger stage, but cleavage and embryonic development were not investigated.

The veliger larva, showing eyespots and otocysts, had a large reddish-brown area between the eyes and on the ventral surface of the foot. A similar color, but much fainter, was also present in the veliger shell, which had a pitted surface similar to that observed in each of the preceding species of the genus. A flat triangular operculum was present, and otoliths were seen, one in each otocyst (Fig. 5a-f).

#### *Cypraea mauritiana* Linnaeus

Fig. 6

In the morning of June 29, 1925, an egg mass was noticed in one of the aquarium tanks in which two of the mollusks were kept. The egg mass was lying on the bottom of the tank beside a rock to which it had probably been attached. Whether or not the animal had been "sitting" on the eggs, as in other cases observed, could not be said. There were about 300 egg cases in the mass. This may have been only a portion of those laid by the mollusk, inasmuch as some could have been eaten by the fishes which were also in the tank.

The egg cases were of a somewhat triangular form and attached to one another at one or more points but were not imbedded in a gelatinous substance as in other species. The egg case measured about 4 mm. in length and 3 mm. at its widest point. The capsular

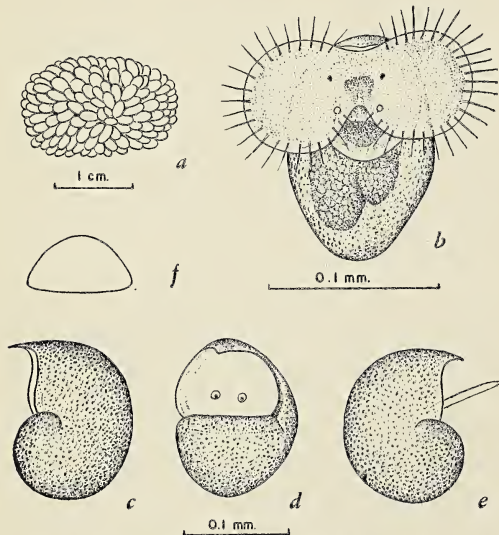


FIG. 5. *Cypraea caputserpentis* Linnaeus. a, Egg mass; b, free-swimming veliger larva, anterior aspect; c-e, shell of free-swimming veliger showing operculum and otocysts with otoliths; f, operculum in surface view.



wall was very thin and transparent, so that the carmine-colored ova could be seen plainly without breaking the capsule.

The ova, of which there were about 1,000 in a case, averaged 0.15 mm. in diameter. Early in the afternoon of the same day they started to divide. Most of them reached the four-cell stage by 4:00 P.M. The mode of division was the same as that observed in the other species.

Not until the seventeenth day did the larvae begin to leave the egg cases. Development had probably been retarded owing to unsuitable conditions, as many egg cases at that time contained dead embryos only.

The veliger shell, which had attained a length of about 0.235 mm., differed from those of the other species which have here been described, particularly in its sculpturing. While a pitted condition of the surface might have been recognized, closely crowded, rounded granules gave to the shell a distinctive appearance. It had a slight golden tinge, a brown columella, and margin of aperture.

The operculum differed from those observed in the other species by being strongly convex on the surface that attached it to the foot (Fig. 6a-e).

Cypraea poraria Linnaeus

Fig. 7

On May 1, 1923, an egg mass of *Cypraea poraria* that was attached to a coral rock from Honolulu harbor was brought to the laboratory. The animal was "sitting" on the egg mass which, at the time it was obtained, was well along in development.

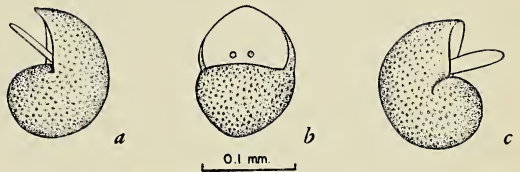


FIG. 7. *Cypraea poraria* Linnaeus. a-c, Shell of free-swimming veliger with opercula and otocysts.

A study was made of the veliger shell alone. This measured 0.14 mm. through its greater diameter, or length. It had a very delicately pitted surface of a pale golden-yellow coloration. The operculum, broadly rounded, was slightly concave longitudinally on its free surface (Fig. 7a, b, c).

PROTECTION OF EGGS BY *Cypraea isabella* LINNAEUS AND *Cypraea helvola* LINNAEUS

As I was fortunate enough to obtain eggs from species of *Cypraea* kept in the laboratory during the summer of 1921, it was possible to observe the strong maternal instinct developed in these mollusks as shown by the protection of their eggs.

*Cypraea isabella* deposited its egg mass on the side of the glass in which it was kept, a few days following its capture. The egg mass, consisting of about 1,500 cases imbedded in a gelatinous matrix, was spread out so as to be conveniently covered by the foot of the animal. Various interesting methods em-

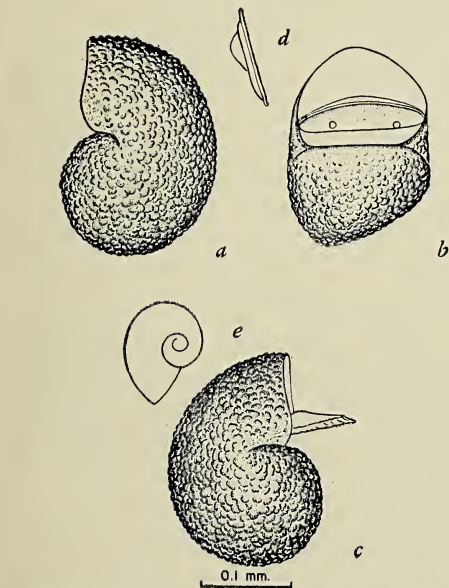


FIG. 6. *Cypraea mauritiana* Linnaeus. a-c, Shell of free-swimming veliger showing operculum lodged in shell; d, operculum in edge view; e, operculum showing spiral turns.

ployed by this mollusk to keep an intruder away made it evident that it was greatly concerned in preventing the removal of any of its eggs.

When an attempt was made to push back the edge of the foot so as to expose the egg cases, the animal would at once move toward the disturbing object and spread out its foot in that direction. When the points of a pair of forceps were placed in front of it, near its head, it would assume an aggressive attitude and advance toward the forceps, touching them or pressing against them with its tentacles and proboscis in a determined manner. But the most striking method employed by the animal to frighten away an enemy consisted of raising the shell as high as possible and then with great suddenness bringing it downward and forward to its normal position, thereby agitating the water around it. These antics would be repeated many times when the animal was disturbed.

Since an enemy from behind or from the sides could not always be seen, the mollusk was guided by touch, to which it was very responsive. When the forceps were placed against the posterior part of the foot, the animal would move back the shell, exposing the posterior part of it by retracting the mantle lobes so the two "eyespot," which are so conspicuous in this species, became visible. Whether this had any significance or not could not be determined. The *Cypraea* did not stop at that, however, for the posterior end of the shell would be brought against the forceps in an attempt to force them away; and by means of the posterior canal of the shell, the animal was able to get a firm hold on the forceps and twist them slightly from side to side. The animal remained constantly on its eggs during the entire 11 days of incubation.

A *Cypraea helvola* with eggs, which was obtained about the same time from a coral rock on the reef, employed, with equal vigor, the methods of defense observed in the above

species, with the exception that it did not seem to use the uncovered posterior end of its shell in any way. This species has no "eyespot" on its shell.

The animal remained on its "nest" until the eggs hatched and liberated the veliger larvae, upon which it promptly left, giving no further evidence of interest in its offspring.

#### Family MITRIDAE

##### Genus MITRA

##### *Mitra astricta* Reeve

##### Fig. 8

On October 17, 1921, I found the spawn of *Mitra astricta* on a rock about 25 meters from shore near the laboratory. There were three adult mollusks on the coral rock containing the eggs, one of them being very close to the egg mass, which was freshly laid. This was taken as good evidence of parentage until later verification could be furnished.

The egg cases, about 100 in number, were separately attached within a cavity of the rock, each one adhering firmly to the firm substratum of the rock by means of a tough, parchment-like base. The egg case was about  $2\frac{1}{2}$  mm. in length, club-shaped or oblong, and consisted of a thin, tough, fibrous capsule of a pale straw color. At the attached end this capsule was continuous, forming a stout, broad base by means of which it adhered to the rock (Fig. 8a). The albuminous fluid with which the capsule was filled contained from 100 to 150 ova (Fig. 8b).

The zygotes were 0.14 mm. in diameter and the type and rate of cleavage were similar to those that had been observed in species of *Cypraea* and *Conus*. In many instances, however, the first division resulted in unequal cleavage, but this might have been an abnormal condition. After the first division, in what appeared to be the normal, or usual, condition, the two equal-sized blastomeres contracted so as to produce an oval body of the two daughter cells. Such a contraction



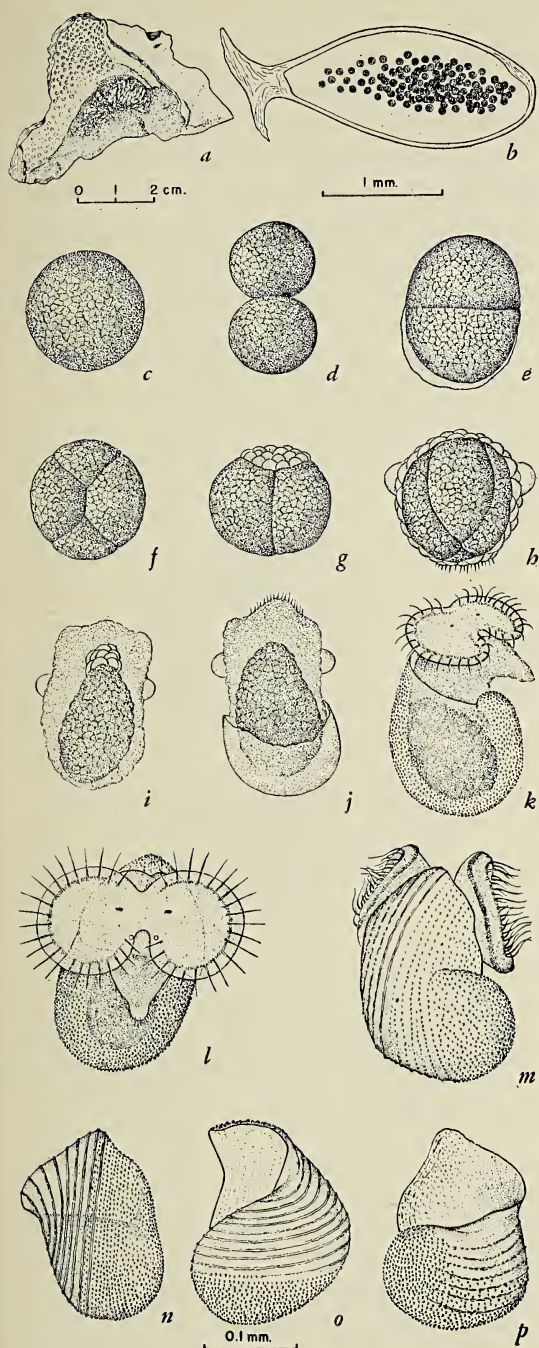


FIG. 8. *Mitra astricta* Reeve. *a*, Egg capsules attached to rock; *b*, enlarged capsule; *c-g*, cleavage stages; *h*, blastula stage; *i*, gastrula stage; *j*, embryo showing rudiment of shell; *k*, veliger; *l*, *m*, free-swimming veliger: *l*, ventral, and *m*, dorsal aspects; *n-p*, shell of free-swimming veliger larva.

of the blastomeres after the first and second divisions seems a usual condition in the gastropods, but it was more pronounced in this case than generally. Cleavage proceeded rather slowly at first, the four-cell stage having been reached only after 24 hours; the following 24 hours presented a stage in which 20 or more micromeres capped the animal pole. There were four macromeres (Fig. 8*f, g*).

After 3 days of development the micromeres had greatly increased in number and constituted about one-half of the surface area of the embryo; a number of those near the vegetal pole had developed short cilia, while the four large macromeres were as yet undivided. Projecting out from each side of the embryo was a large micromere, clear like the others, about half of its sphere protruding beyond the surface of the ectoderm. This stage was evidently comparable to the blastula, although the space required for the segmentation cavity was entirely obstructed by the large macromeres (Fig. 8*b*).

A day later—after 4 days' development—the embryo had become elongate and the micromeres had surrounded by a complete layer (ectoderm) the dark, conspicuous macromeres, which also had taken on an elongate form, but the boundaries of which had now become so obscure that it was impossible to determine their number. At the anterior end of the macromeres there was a cluster of rather large, clear cells, probably mesodermal. Anteriorly the ectodermal layer, in connection, perhaps, with an underlying mesoderm, had developed three slight lobes, the rudiments of the velum. Cilia could not be seen although they must have been present as the embryo showed considerable activity. This was the gastrula stage (Fig. 8*i*).

After the sixth day a shallow cup-shaped shell surrounded the posterior region of the embryo (Fig. 8*j*). Seven days of development brought out the veliger stage. A bilobed ciliated velum which had minute eyespots was found. A short pyramidal foot was

present, and a finely granulated shell surrounded the greater part of the larva (Fig. 8k).

From this time on, development proceeded rather slowly, no marked changes taking place until the free-swimming stage was reached, after 14 days of incubation. The velum consisted then of two circular lobes with a double line of purplish-pink around the borders. Eyes and otocysts were present. The foot terminated in a blunt translucent tip set with bristles. The operculum was observed in only one specimen and was small and rudimentary (Fig. 8l, m). The first whorl of the shell started with a corkscrew spiral as in the common snail. The apex was sprinkled with granulations which tended to be in rows distally; while the distal half of the veliger shell was ornamented with granular spiral ridges. These ridges seemed to correspond to the transverse striae on the whorls of the adult shell. The shell was colorless and about 0.22 mm. long (Fig. 8n-p).

### *Mitra auriculoides* Reeve

Fig. 9

On December 21, 1923, while collecting on the reef about 15 meters offshore near the laboratory, I found a group of egg cases attached to the undersurface of a rock, accompanied by a *Mitra auriculoides*. There could hardly be any more doubt that the egg cases belonged to this mollusk than in the case of *Mitra astricta* obtained 2 years before under similar circumstances. Furthermore the comparison of egg capsules, veliger larvae, and shells bore out this conclusion.

The egg cases, about 100 in number, were crowded closely together and occupied nearly 2 square cm. of the rock surface. The egg case, resembling greatly that of *Mitra astricta*, was club-shaped, about 4 mm. in length, and was attached to the rock at one end by a basal extension. The capsule wall was very thin and there were about 200 ova to the capsule.

When the egg mass was found the capsules contained embryos in an advanced veliger stage, the coloring of which imparted a pale brownish tinge to the capsule (Fig. 9a, b).

On December 28, the young escaped from their enclosures, and the close resemblance to both larva and shell of *M. astricta* was obvious. The same double band bordering the veliger lobes was present, and the ridges and granulations on the shell were distributed as in the other species. The operculum, however, showed a marked difference; while it was almost absent in *M. astricta*, it was well developed in this species. The foot was pro-

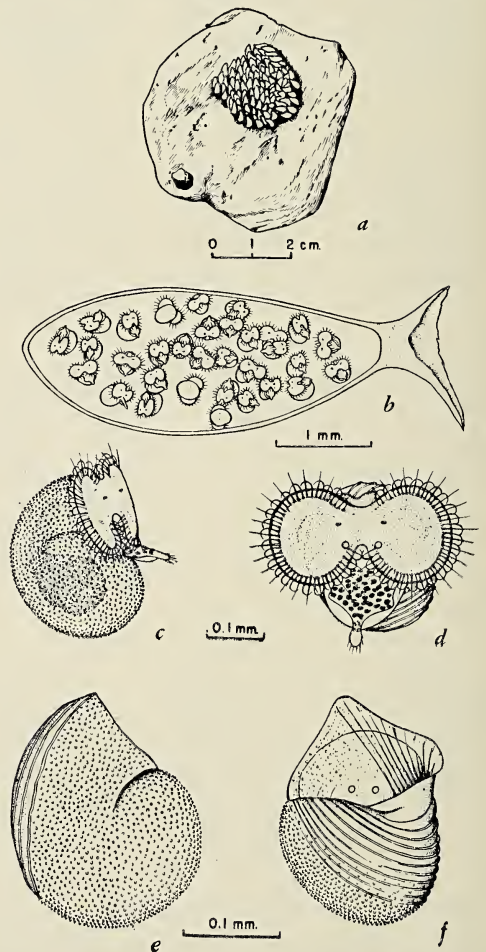


FIG. 9. *Mitra auriculoides* Reeve. a, Egg capsules on rock; b, magnified capsule with embryos in veliger stage; c, d, free-swimming veliger; e, f, shell of free-swimming veliger.



duced laterally into two angular processes, and anteriorly, as in *M. stricta*, into a blunt, rounded process with bristles. Eyes and otocysts were present. The marginal bands on the velum were greenish-brown. Numerous spots of the same color occurred also on the foot. The length of the shell was 0.25 mm. (Fig. 9c-f). The larvae showed a strong positive phototropism.

# Family CONIDAE

## Genus CONUS

### *Conus tahitensis rattus* Hwass

#### Fig. 10

While collecting on the outer reef near the Elk's Club at Waikiki during the morning of August 4, 1921, I picked up a specimen of *Conus tahitensis* in the act of depositing eggs. I broke off the rock to which the egg capsules were attached and took it to the laboratory.

There were 22 egg cases of a soft, thin structure and of a comparatively large size, about 11 x 15 mm. Each egg case contained about 2,000 ova of rather small size, 0.125 mm. (Fig. 10a).

The ova, in respect to distribution of yolk (deutoplasm) and cytoplasm, agreed closely, insofar as could be observed without special preparations, with those of *Cypraea* and *Mitra*.

The early stages of cleavage were observed in a capsule about 6 hours after deposition. The first division resulted in two cells of equal size. These rounded out independently until the two cells were joined to each other by a very small area. Soon they contracted toward each other to assume the appearance they had before the first division was complete (Fig. 10b, c, d). The second division, resulting in four cells of equal size, had occurred about 1 hour after the first. Here again, as in the first division, the cells were rounded off and standing out prominently.

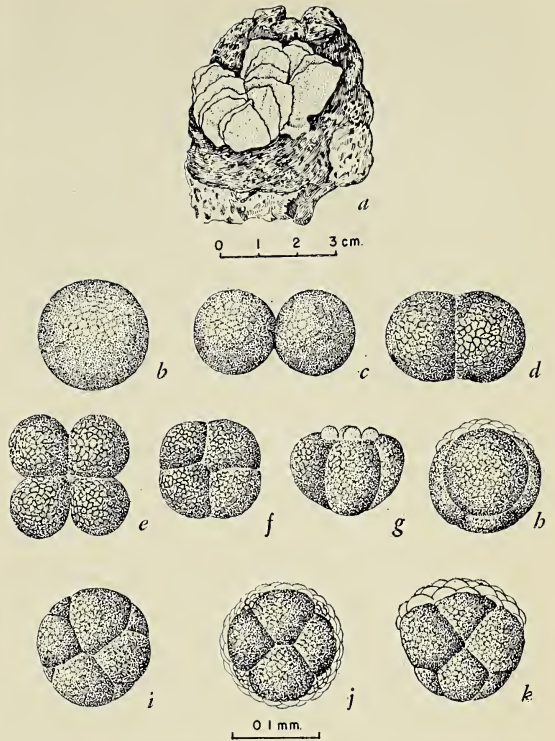


FIG. 10. *Conus tahitensis rattus* Hwass. a, Egg capsules attached to rock; b-k, cleavage stages from the ovum to the blastula stage.

These again became pulled toward the center, so that the entire mass became neatly spherical (Fig. 10e, f). The next cleavage was unequal, resulting in four micromeres and four macromeres, as in *Cypraea* and *Mitra* (Fig. 10g). Succeeding cleavages resulted in a cap of micromeres at the animal pole. The macromeres now divided nearly equally into four cells of lesser size which came to lie at the equator, and four larger ones which surrounded the vegetal pole. The micromeres soon extended to the equator, covering half of the sphere of the embryo and projecting out beyond the macromeres (Fig. 10h, i, j).

This was the blastula stage and the embryo now began to show activity. It appeared that in some of the embryos another division of the four equatorial macromeres had taken place, as some embryos had 12 macromeres



This was also observed in *Cypraea carneola* and is probably a common condition (Fig. 10*k*). Owing to the loss of all the larvae, no further observations on the development were made.

In February, 1923, another *Conus tabitensis* with egg capsules was found near the laboratory. The egg capsules were much smaller, but agreed in other respects with the one described, i.e., in color, texture, number, and size of ova. As in the previous lot none developed beyond the blastula stage.

### *Conus omaria* Hwass

Fig. 11

On May 19, 1921, I found, near the laboratory, a number of *Conus* egg cases which were attached to the underside of a rock. Under this rock also was an adult *Conus omaria*, a rather rare species on this reef. The egg capsules differed from all those previously observed in that only a few of them were attached directly to the rock; the greater number, about 34 in all, were joined to one another, forming arches and bridges (Fig. 11*a*).

Upon examining the contents of one of these capsules, I found zygotes in very early cleavage stages. Some were still unsegmented, while a number were in the two-cell stage, the result of an equal division. A few had undergone a second division which was equal, four blastomeres of a smaller size resulting.

The capsules of this species, measuring about 11 mm. in length and 8 mm. in width, contained a small number of large ova, 0.47 mm. in diameter, often less than 50 in one capsule. The zygotes failed to develop when removed from the capsule, so it was necessary to open one each day to follow their progressive development. Five days after they were obtained some of the embryos had begun to form a shell. And after 11 days of incubation they had attained well-advanced stages, a large shell having formed about the

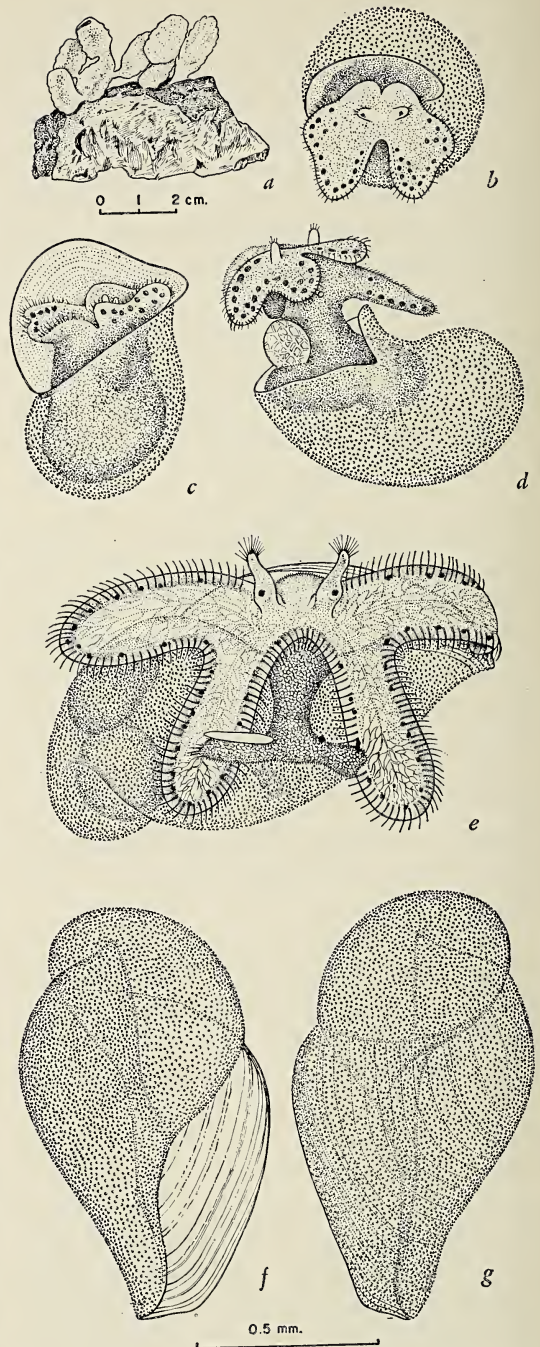


FIG. 11. *Conus omaria* Hwass. *a*, Egg capsules attached to rock; *b-d*, stages of development in veliger larva, heart showing as a globular body in *d*; *e*, veliger larva after normal release from capsule; *f*, *g*, shell of veliger larva.



body. The veliger lobes had also attained a large size, yet the cilia bordering them remained short. The heart could be seen distinctly as a single-chambered oval bag on the dorsal side posterior to the veliger lobes. Its alternate contraction and expansion would change its volume about 100 per cent. The large veliger lobes were bordered by a single row of yellowish pigment cells. A pair of blunt papilla-like tentacles supporting the eye were tipped with a few short bristles. The shell showed a fine granulation. No operculum was present on the large foot (Fig. 11*d*).

At the sixteenth day of incubation some changes were noticeable. The two veliger lobes had developed greatly, each having a deep lateral indentation. The cilia also had increased greatly in size and were beating rhythmically, keeping the animal upright with the apex of the shell against the bottom. The large bilobed foot supported a small operculum on one of its lobes and was covered with very fine cilia; a few prominent bristles were present at its opercular end. Two prominent tentacles, bearing the eyes on basal swellings and beset at their extremities with a large tuft of bristles, occupied a central position on the veliger lobes (Fig. 11*e*).

At this stage, 16 days of incubation after the beginning of cleavage, the larvae began to escape into the water, but, unlike those of other species here observed, they remained within the albuminous substance of the capsule which had been discharged into the water and did not attain the power of swimming at any time while under observation. This inability to swim may be ascribed to the great size and weight of the shell, some of the veliger shells having attained a length of over 1.25 mm. with about one and a half volutions (Fig. 11*f, g*). A fine granulation covered its entire outer surface, which had taken on a faint golden tinge, most pronounced anteriorly. The columella seen through the quite transparent shell had a pale rose tinge.

This coloration of the veliger shell is an approach to that in the shell of the adult.

Egg capsules corresponding to those of *Conus omaria* were found near the Marine Laboratory, May 25, 1922, but were of a larger size than the first lot. These capsules contained advanced veligers, one capsule containing about 40, another as many as 150 embryos. Some of the larvae of this lot were kept for over a week after their escape from their capsule without ever showing signs of swimming. Some, however, would drag their shells on the bottom of the dish by means of the propelling force of their velar cilia. A number of the larvae were normally expelled from the capsule, which seemed to be effected by a dissolution of the "window" at the free, or distal, end of the capsule, followed by a contraction of the capsular walls, resulting in a squeezing out into the water of the albuminous substance containing the larvae. It may be that both chemical and mechanical agents are responsible for this occurrence, and that the larvae, at the time of their liberation, emit some secretion which brings about the desired results.

A circumstance which might be correlated with the absence of a free-swimming stage of this species is the fact that *Conus omaria* occurs in many varietal forms in various parts of the Hawaiian Islands; so much so that some authorities are inclined to consider some of them distinct species.

One might suppose that the free access to widespread areas possessed by those species having such an efficient mode of dispersal as a pelagic veliger larva would serve to break down varietal strains which might be in process of development and thus tend to stabilize the species, whereas an immotile larva, as here observed in *Conus omaria*, would have the opposite effect.

*Conus catus* Hwass

Fig. 12

On June 12, 1922, a mass of egg capsules

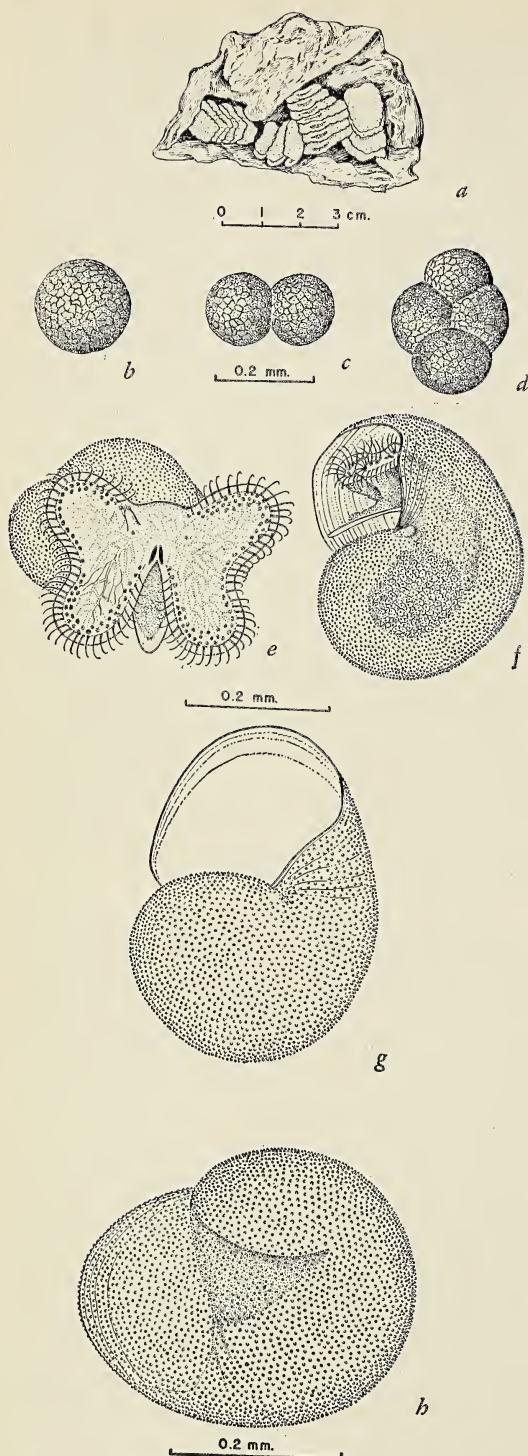


FIG. 12. *Conus catus* Hwass. *a*, Egg capsules attached to rock; *b-d*, cleavage stages; *e, f*, free-swimming veliger larva; *g, h*, veliger shell of free-swimming larva.

attached to a rock with a *Conus catus* beside it was found near the Marine Laboratory. These capsules, of a pale straw color, were thin, semi-transparent, yet firm and rigid, measuring about 9 x 12 mm., and containing from 500 to 1,000 ova (Fig. 12*a*).

The diameter of the zygotes averaged 0.2 mm., and cleavage was similar to that observed in other species of the genus, i.e., equal in the first and the second division, unequal in the third (Fig. 12*b, c, d*).

The larvae attained the free-swimming veliger stage in 15 to 16 days, at which time the shell measured about 0.375 mm. in length. The velar lobes were of medium size with a lateral indentation which partly divided them, but to a far less extent than in the veliger of *C. omaria*. The lobes were bordered by a continuous line of many pale green pigment spots which were increased in number at the extremities of the lobes so as to form two or three rows. Eyes were distinct with a rather short tentacle at the right eye. The mouth was marked by an elongate black streak on each side. The foot was somewhat narrow and pointed, bearing an operculum which extended well beyond it distally. Fine bristle-like processes were present (Fig. 12*e, f*). The shell was ovate and densely granulate, consisting of about one spiral turn. Some of the shells had a faint reddish tinge on the outer lip (Fig. 12*g, h*).

#### *Conus hebraeus* Linnaeus

Fig. 13

On March 22, 1921, a *Conus hebraeus* kept in the laboratory in a pan of water was found in the act of laying an egg case. Further inspection of the pan resulted in the discovery of other cases. The egg case being laid was partly held by the animal and was of a jelly-like consistency. Upon contact with the water, the capsular walls gradually hardened and it assumed the appearance of the other egg cases. The capsules were very pale straw-



colored with corrugated distal margins. They were almost square and measured about 10 mm. across (Fig. 13*a*).

Cleavage was not investigated in this species. After a period of 9 days the embryos had begun to show activity, short cilia having developed in three regions near the anterior end of the body. A shell had also begun to form, taking the form of a slipper, and beginning, apparently, at a dorsoposterior region of the body of the embryo, at which place it was attached (Fig. 13*b, c*). As growth of the shell progressed, it spread to the side, becoming cup-shaped. This stage was observed 1 day later (Fig. 13*d, e*).

In the course of 24 hours an interesting transitional stage occurred. The lateral ciliated areas constricted to form veliger lobes. The cilia grew rapidly and other cilia appeared along the borders of the lobes; the anterior cilia remained short, as did those now visible on the foot. The veliger lobes gradually unfolded and the embryo began to assume the appearance of the free-swimming form. The shell covered the greater part of its body.

The embryo quickly grew into the free-swimming larva as the veliger lobes were completely unfolded and the cilia became capable of propelling the animal through the water. Since simultaneous development of the embryos in the capsule is not the rule, a provision seems to have been made for those that have been retarded in that the capsule does not expel its contents of young in favor of a minority, but remains closed until the great majority have reached the stage where the new environment becomes imperative.

At the free-swimming stage the rather orbicular veliger lobes were bordered with a row of pale-green pigmented cells; bristles projected from the tip of the ciliated foot, which was without an operculum and pointed. Eyes were present. The shell, measuring 0.28 mm. in length, bore a fine granulation (Fig. 13*f, g*).

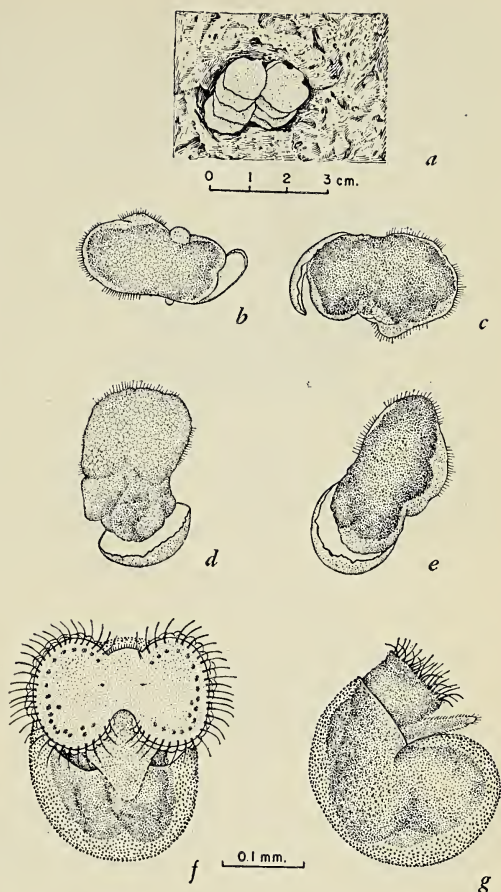


FIG. 13. *Conus hebraeus* Linnaeus. *a*, Egg capsules attached to rock; *b, c*, trochophore larvae showing beginning of shell formation after 9 days of incubation; *d, e*, trochophore stage after 10 days incubation; *f*, free-swimming veliger, ventral aspect; *g*, free-swimming veliger, lateral aspect.

#### *Conus sumatrensis* Hwass

##### Fig. 14

May 16, 1921, while collecting about 50 meters off the Marine Laboratory, I found a group of 34 egg cases of *Conus* attached to the lower side of a piece of coral, and right beside them was a *Conus sumatrensis*. Inasmuch as the zygotes were in very early stages of cleavage, there could be little doubt as to their identification.

The egg cases, quite unlike those of other known species of *Conus* described in this paper, are very soft and thin; they average

13 x 20 mm. Thousands of ova, which in this species were quite small (0.14 mm.), were contained in a capsule (Fig. 14a-d). Early cleavage stages only were observed. Numerous polar bodies were seen with them.

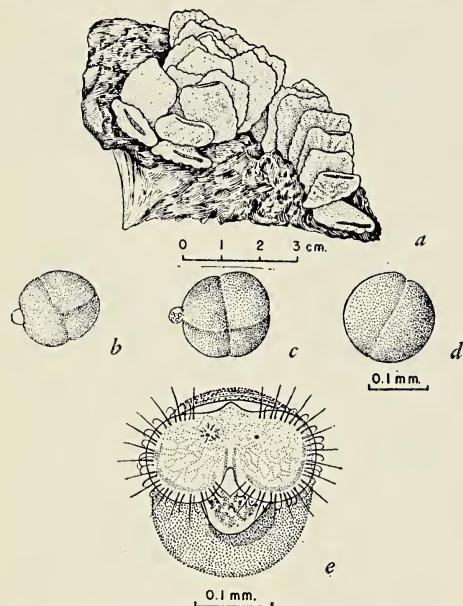


FIG. 14. *Conus sumatrensis* Hwass. a, Egg capsules attached to rock; b-d, cleavage stages showing polar bodies; e, free-swimming larva, ventral view.

After 4 days of incubation the embryos began to show activity and a shell had begun to form. After 7 days the anterior end of the embryo had assumed a trilobular form with short cilia. A shell covered the greater part of the body. On the twelfth day of incubation the young began to leave their capsules, entering upon their free-swimming larval stage. The veliger lobes were rounded and pigmented with green as in *C. hebraeus*, but unlike the larva of that species, a rounded foot, with an operculum projecting beyond it, was present. The shell, which measured 0.25 mm. in length, was covered with a fine granulation (Fig. 14e).

#### *Conus abbreviatus* Nuttall

##### Fig. 15

On March 15, 1923, a dozen egg capsules

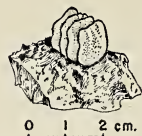


FIG. 15. *Conus abbreviatus* Nuttall. Egg capsule attached to rock.

were deposited by a *Conus abbreviatus* which had been isolated in the laboratory. The capsules averaged 8 x 10 mm., had firm and rigid walls with smooth sides and margins, except for the distal margins, which were slightly corrugated (Fig. 15). A slight reddish tinge was discernible. Cleavage and larval development were not investigated.

The egg capsules of *Conus* have not been of uncommon occurrence in the shallow water of the Waikiki reef near the Marine Biological Laboratory. Several different forms have been found and specific distinction could often be made by the differences in size, shape, and firmness, and perhaps to some extent by color. A comparison between ova and veliger larvae of a few unidentified capsules, with ova and veligers of determined species, has shown a corresponding distinction. In other words, specific characters may be recognized in the egg capsules.

The capsules in all the species under observation had tough parchment-like walls with more or less corrugated borders. A slit through which the young might escape when they reached the free-swimming stage was present at the distal end of the capsule. During incubation this slit was closed by a clear, semi-transparent substance which then appeared as a window. My observations have not convinced me that the young may not also be released by a rupture of the capsule.

The following species of *Conus* have been found in the living state within wading distance of the Marine Laboratory:

*C. abbreviatus* Nuttall

*C. catus* Hwass

*C. flavidus* Lamarck



- C. hebraeus* Linnaeus  
*C. imperialis* Linnaeus  
*C. lividus* Hwass  
*C. miles* Linnaeus  
*C. nanus* Broderip  
*C. omaria* Hwass  
*C. sumatrensis* Hwass  
*C. tabitensis rattus* Hwass

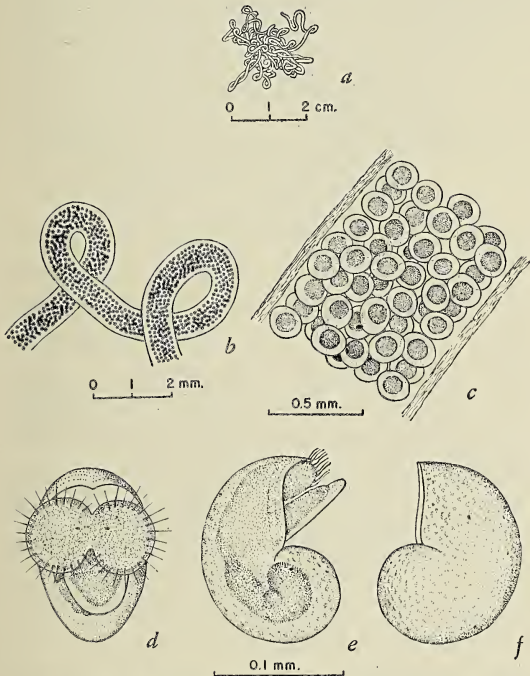


FIG. 16. *Clava obeliscus* (Bruguiere). a, Egg filament; b, portion of filament enlarged; c, section of filament highly magnified; d, e, free-swimming veliger larva: d, ventral, and e, lateral aspects; f, shell of free-swimming veliger.

### Family CERITHIDAE

#### Genus CLAVA

#### *Clava obeliscus* (Bruguiere)

#### Fig. 16

An egg filament of *Clava obeliscus* was deposited in a dish by a specimen of the mollusk on March 28, 1922.

The egg structure was a pale cylindrical filament about 0.75 mm. in diameter, twisted and coiled upon itself to form a tangled mass.

The parchment-like walls of the filament were thick and fibrous. The filament contained a closely packed mass of ova, lying about five abreast in cross section. The ovum, measuring about 0.9 mm. in diameter, was surrounded by a hyaline membrane whose diameter was about twice that of the ovum (Fig. 16a, b, c). Development was not investigated. The embryos reached the free-swimming veliger stage in the short period of 6 days. The larva was of a pale straw color. Eyes were present, as well as otocysts; the veliger lobes were rather small, but the operculum was large and rounded. The shell was about 0.16 mm. in length and slightly pitted, much resembling that of the *Cypraea* veliger (Fig. 16d, e, f).

### Family STROMBIDAE

#### Genus STROMBUS

#### *Strombus maculatus* Nuttall

#### Fig. 17

In a dish containing two specimens of *Strombus maculatus* several egg structures were deposited on March 16, 1922. These egg structures, which were lying unattached on the bottom of the dish, consisted of a

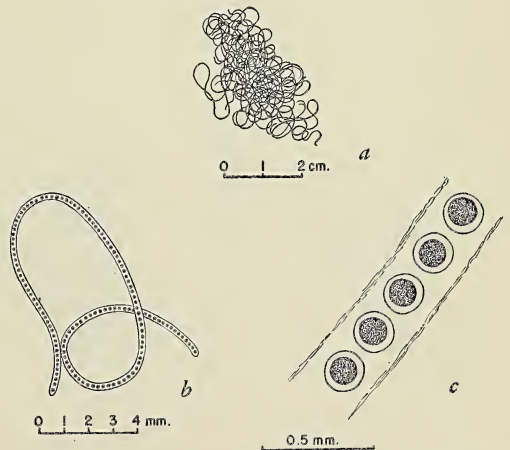


FIG. 17. *Strombus maculatus* Nuttall. a, Egg filament; b, filament enlarged; c, section of filament highly magnified.

maze of very fine pale-yellow threads of various lengths, tangled and glued together as if they were one continuous coil. When magnified, the thread proved to be a cylindrical gelatinous tube with a single row of ova placed in its center and strung out like a single strand of beads, each ovum being surrounded by a globular membrane.

The diameter of the filament was about 0.25 mm., that of the membrane 0.13 mm., and that of the ovum about 0.10 mm. (Fig. 17*a, b, c*). The zygotes died at the morula stage.

### Family MURICIDAE

#### Genus MORULA

#### *Morula dumosa* (Conrad)

#### Fig. 18

On July 1, 1923, an egg filament was laid in the laboratory by a specimen of *Morula dumosa* which had been kept for some time. This was a white, cylindrical filament of about two volutions and of about 25 mm. in length. The walls of the coil were fairly thick and the cavity was packed with ova. Each ovum was enclosed in a hyaline envelope of

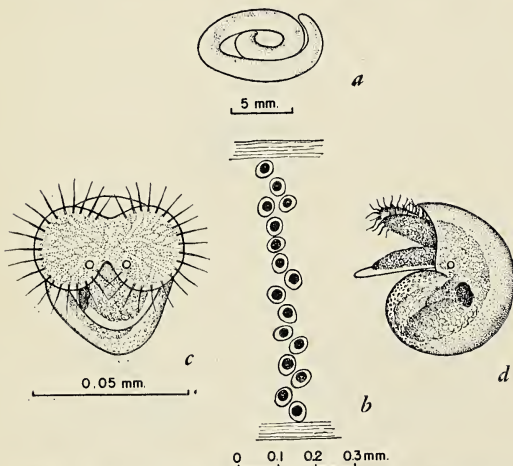


FIG. 18. *Morula dumosa* (Conrad). *a*, Egg filament; *b*, section of filament magnified; *c*, *d*, free-swimming veliger larva: *c*, ventral, and *d*, lateral aspects.

a circular to oval shape, the ovum within measuring about 0.03 mm., therefore among the smallest recorded in this paper (Fig. 18*a, b*).

The free-swimming veliger larva was of a pale-brownish tinge with a large black pigment spot near the base of the foot. Otocysts were present but not eyes. The veliger lobes were round and bore large cilia. Foot and operculum were well developed (Fig. 18*c, d*).

### Family DOLIIDAE

#### Genus TONNA (= DOLIUM) (Linnaeus)

#### *Tonna perdix* (Linnaeus)

#### Fig. 19

On June 22, 1924, Ted Dranga, an experienced diver and collector of marine organisms, located near Kapapa Island, Kaneohe Bay, what appeared to be the egg structure of *Tonna perdix*. There were several of these structures about 3 meters from a group of the mollusks. The largest egg structure was nearly circular in form with a diameter of about 15 cm. and with a thickness of about 2 mm. An indentation of about 6 cm. occurred at one side, by which the structure had its attachment, so the form of it is not unlike that of a leaf of a pond lily.

Within the thick parchment walls were 3,076 egg envelopes, neatly arranged in semi-circular rows. These egg envelopes were cylindrical with rounded ends, measured about 1 x 2 mm., and contained an average of 49 ova. An estimate of the number of ova in the total structure is 150,724. The ova were rather large, averaging about 0.30 mm. in diameter, and were grouped together within their envelopes so as to form elongate masses with a constriction at the middle. They had a pale-orange tinge (Fig. 19*a, b*).

When the egg structures were brought to the laboratory, the zygotes were in early stages of cleavage. Some were probably in the morula stage, having four macromeres



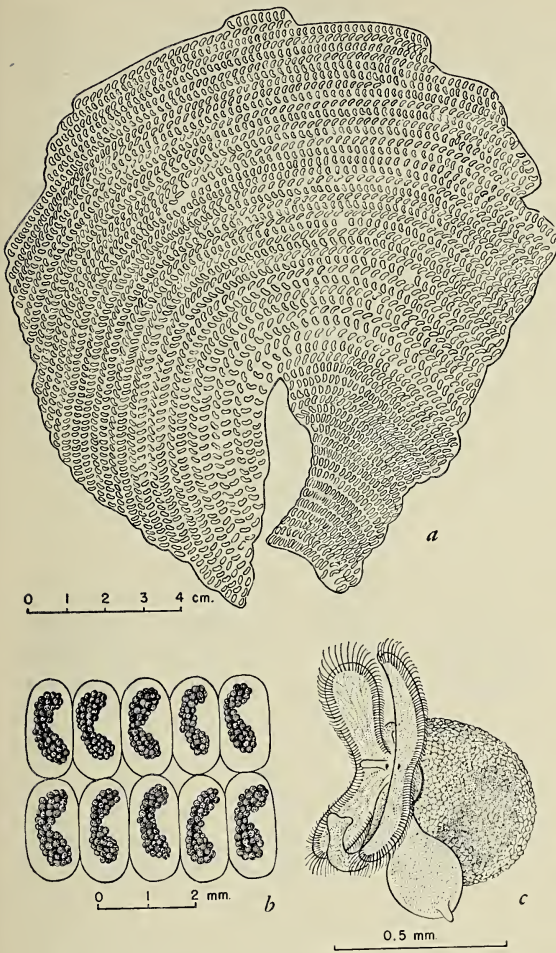


FIG. 19. *Tonna* (= *Dolium*) *perdix* (Linnaeus). *a*, Egg structure; *b*, egg envelopes with grouped masses of ova; *c*, free-swimming veliger larva showing a prominent proboscis.

and numerous micromeres, the latter reaching about to the equator. A day or two later a stage in which the embryos showed a slight amount of movement was attained. This was probably the blastula stage, the segmentation cavity being occupied by the large macromeres.

The length of time required for the larva to become a free-swimming veliger was not recorded. At this stage the larva was provided with large veliger lobes, eyes, a long proboscis, and a rounded foot with an operculum extending beyond its borders. A pale-

yellow color was seen in the animal's visceral mass. The shell, measuring 0.55 mm. in length, was covered with a fine reticulum of slightly elevated polygonal areas (Fig. 19*c*). It was tinged with carmine along the margin.

It is of interest to compare the egg structure and larva of this species with those of one recorded from the Iranian Gulf by Gunnar Thorson (1940: 192-195).

## Family LITTORINIDAE

### Genus LITTORINA

#### *Littorina pintado* Wood

#### Fig. 20

A large quantity of eggs was obtained from a number of specimens of *Littorina pintado* which were kept in a glass of water in the laboratory. The eggs were deposited during the night and in the morning were found scattered in profusion over the bottom of the glass.

Each ovum, contained within a hyaline membrane, was usually enclosed in a capsule alone; rarely two or more ova were present. The capsules were somewhat globular or pyriform, flat on one surface and convex on the other with a transverse diameter of the flat

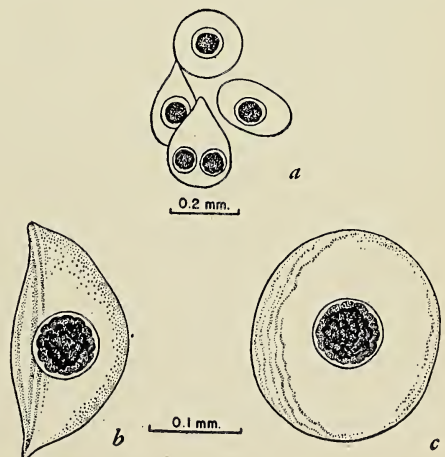


FIG. 20. *Littorina pintado* Wood. *a*, Egg capsules enlarged; *b*, *c*, egg capsule magnified, and seen from edge and flat surface.

surface of about 0.19 mm. The ovum measured about 0.08 mm. (Fig. 20*a, b, c*). Development of the ova was not investigated.

It is of interest to compare the egg capsules and ova of this species with those of two other species of the genus from Bermuda, which have been recorded by Dr. Marie V. Lebour. They are *L. zigzac* Dillwyn (Lebour, 1945) and *L. neritoides* (Lebour, 1935).

## Order OPISTHOBRANCHIATA

### Suborder TECTIBRANCHIATA

#### Family APLYSIDAE

#### Genus TETHYS (= APLYSIA)

#### *Tethys* (= *Aplysia*) *grandis* (Pease)

#### Fig. 21

On November 9, 1920, two egg filaments of *Tethys grandis* were found beside the Marine Laboratory pier adhering to a stone under which were two of the animals. Since then numerous filaments have been seen on the loose stones at the same place, to which the mollusks come in large numbers. They were especially abundant during the months of November, December, and January, which seemed to be the main spawning season. They were also present at other times of the year, in August for example, and their spawn would invariably be found with them.

The filament of this mollusk resembled a very tangled bundle of yellow thread with a circumference of about 15 cm. and a thickness of about 3 cm. It was supplied with thick walls and contained masses of oval or rounded hyaline membranes packed together throughout its length. These hyaline membranes lay 3 or 4 abreast in the filament and each contained 7 to 15 ova (Fig. 21*a, b*).

Early stages of cleavage were investigated in different filaments of the species. In one instance, the first cleavage was equal, the second unequal and resulted in two smaller blastomeres asymmetrically placed. This would indicate spiral cleavage. The ovum measured about 0.085 mm. (Fig. 21*c-f*).

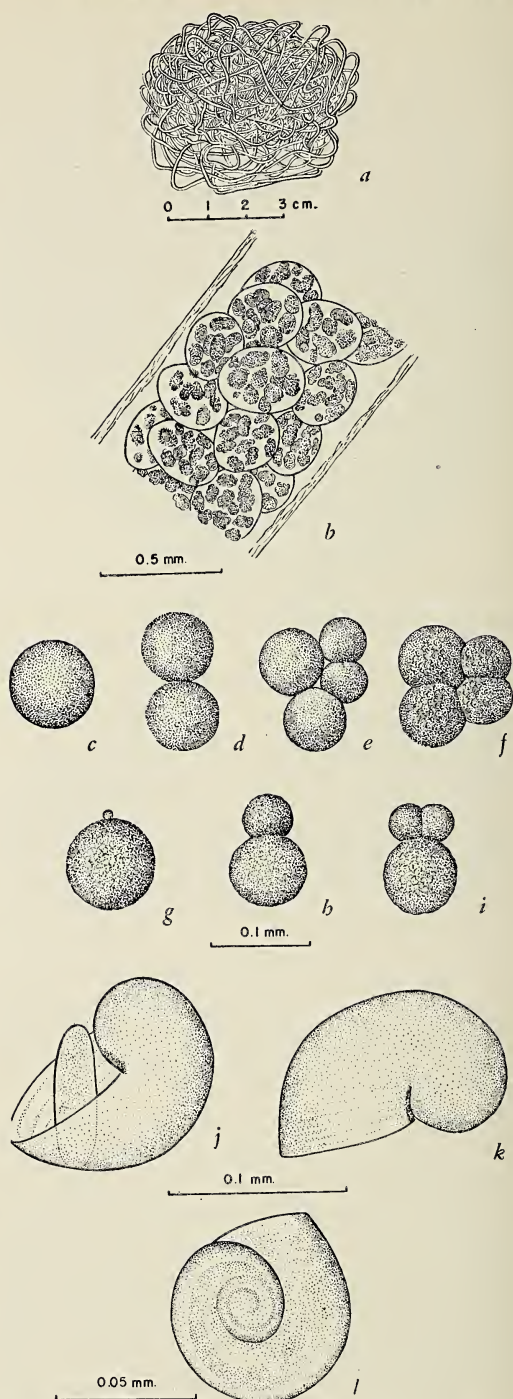


FIG. 21. *Tethys* (= *Aplysia*) *grandis* (Pease). *a*, Egg filament; *b*, magnified section of filament with active embryos; *c-f*, first type of cleavage; *g-i*, second type of cleavage; *j, k*, shell of free-swimming veliger stage showing operculum (*j*); *l*, operculum more highly magnified.



A month later in the season another type of cleavage was observed in which the first was unequal and the second resulted in an embryo with three blastomeres, only the smaller blastomere of the first division having divided (Fig. 21*g, h, i*).

The total period required for incubation was not recorded. The free-swimming larva was provided with a coiled shell and a large, rounded operculum (Fig. 21*j, k, l*). The free-swimming veliger larvae were kept 21 days in a large glass container in the laboratory. During this period no indication of metamorphosis into the adult condition was discernible; only a slight growth of the shell could be detected.

After several days of incubation the hyaline envelopes within the filaments could be seen to contain a whirling mass of embryos in various stages of development, as well as zygotes in early cleavage stages. The obvious effect of this action seemed to result in the survival of the stronger and more advanced embryos over the weaker and retarded individuals, which were knocked to pieces and consumed by the stronger. Thus, a form of cannibalism existed (Fig. 21*b*).

Inasmuch as this mollusk is of quite common occurrence inshore during the cooler season of the year and is a very prolific egg layer, its spawning habit could be observed in the laboratory, where several of the animals were kept in a trough with running water in which a number of coral rocks were placed which bore algae and other marine organisms.

When the animal deposited its filament, it mounted the rough surface of a coral rock and placed the right side of its head against the surface of the rock, bringing the adhesive filament into contact with it. The filament passed along the genital groove between the parapodial lobes on to the right side of the head.

As the filament was extruded, the animal turned its head from side to side in a desul-

tory fashion with the result that successive loops formed an irregular, tangled, thread bundle adhering to the rock. One such filament was found to have a length of 5.25 meters when it was unraveled. It contained an estimated number of ova reaching the high figure of 742,720.

Freshly deposited filaments were pale yellow, but as the embryos developed the filaments became quite brown. Under favorable conditions of development, the free-swimming young were seen to escape simultaneously in great swarms, the egg filament being literally torn to bits.

### *Tethys* (= *Aplysia*) *bipes* (Pease)

Fig. 22

Like the preceding species, this large form occurred commonly under loose stones along

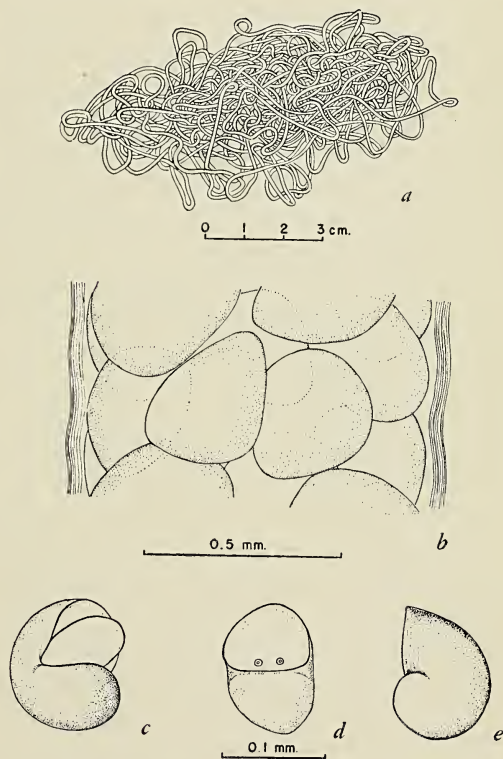


FIG. 22. *Tethys* (= *Aplysia*) *bipes* (Pease). *a*, Egg filament; *b*, section of filament magnified to show egg envelopes; *c-e*, shell of free-swimming veliger showing operculum and otoliths.

the shore during the cooler months of the year, at which time its filaments were also found in abundance. As in the preceding species the fresh filament was white or pale yellow and, as development of the young progressed, it turned to a yellowish-brown.

The structure of the filament and the type of cleavage agreed in nature with those of *T. grandis*. However, a note on the veliger shell is of interest. The shell measured about 0.125 mm. in length and consisted of about one volution, was a light golden-brown in color, darkest along the columellar line. The operculum was large and round as in *T. grandis*. Otoliths appeared distinctly within the otocysts (Fig. 22*c, d, e*).

### *Tethys* (= *Aplysia*) *elongata* (Pease)

#### Fig. 23

Early in March, 1923, a specimen of *Tethys elongata* found near the Elk's Club, Waikiki, was brought to the laboratory. This animal was in general of a much darker color than the species but otherwise seemed to agree and might be considered a color variety. Two months later five more specimens like it were found in the same location.

An egg filament was deposited by this mollusk in the laboratory. This was a pale green, tangled, cylindrical filament of about 0.5 mm. in diameter. The lumen of the filament was closely packed with globular hyaline capsules with an average diameter of 0.125 mm., lying about four abreast in a cross section and each containing one ovum.

The first cleavage of the zygote was usually equal, while the second was unequal, resulting in two micromeres and two macromeres. The micromeres soon divided, giving the embryo its triangular appearance, corresponding, perhaps, to the morula stage (Fig. 23*a, b*).

The free-swimming veliger stage was reached in 11 days, and the larva then, quite colorless, was provided with otocysts but with no eyes. The shell, which was about 0.125

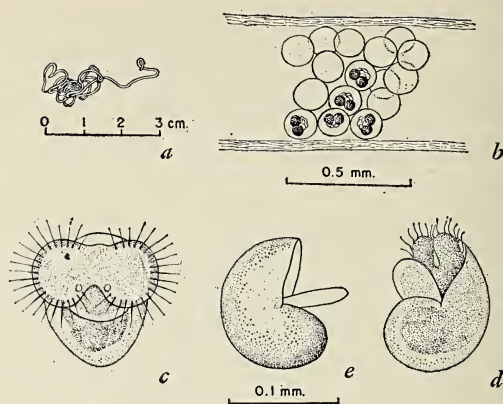


FIG. 23. *Tethys* (= *Aplysia*) *elongata* (Pease). *a*, Egg filament; *b*, magnified section of filament with early cleavage stage; *c, d*, free-swimming veliger larva; *e*, shell with operculum of free-swimming veliger.

mm. in length, had a golden tinge and a reddish columellar region. A well-developed operculum was present (Fig. 23*c, d, e*).

### Genus DOLABRIFERA

#### *Dolabrifera olivacea* Pease

#### Fig. 24

For a long time I sought in vain for the spawn of this mollusk, so common under loose, flat, shore rocks. Finally on February 18, 1922, an animal that was kept in a glass jar laid a peculiar, flat egg ribbon.

Later in the season—on May 25—I found, on the underside of a number of concrete slabs to which the mollusks were clinging, many of their ribbons. This egg structure is easily overlooked as it is clear and colorless—a flat band with the flat side attached to the smooth surface of a rock or other object, and spread out so as to cover a surface of 5 or more square centimeters. The ribbon rarely overlapped, but was often spread out so neatly that it formed a series of slightly curved parallel rows (Fig. 24*a, b*).

I happened to observe one of the mollusks in the act of laying eggs. The ribbon passed anteriorly, from the genital pore in the dorsal



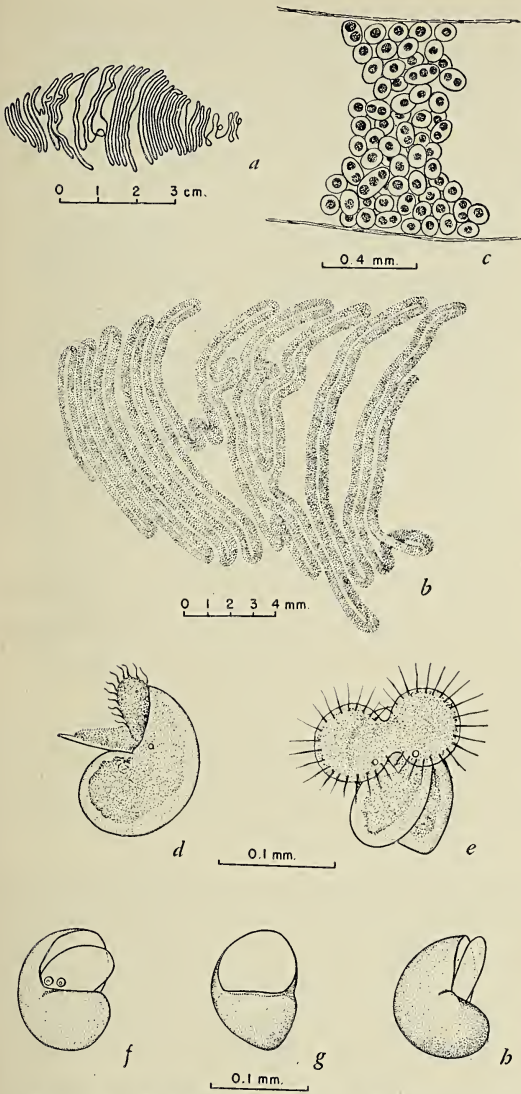


FIG. 24. *Dolabrifera olivacea* Pease. a, Egg ribbon; b, portion of egg ribbon enlarged; c, section of egg ribbon magnified to show arrangement of ova in egg envelopes; d, e, free-swimming veliger, lateral (d) and ventral (e) aspects; f-h, shell of free-swimming veliger showing operculum and otoliths.

slit, along the genital groove to the right side of the buccal disk. The mollusk then slowly moved its head from side to side, gradually backing up and carefully avoiding any overlapping of the ribbon.

As the embryos developed, the egg structures assumed a brownish or greenish color.

Under magnification the egg ribbon was found to be closely packed with hyaline capsules, globular, oval, and a few oblong in form, each containing from one to three ova, usually one (Fig. 24c). The ova were about 0.08 mm. in diameter.

The free-swimming veliger stage was reached in 9 days. Larva and shell bore a close resemblance to those of *Tethys*. There was a well-developed, broad operculum extending well beyond the foot. No eyes were present but otocysts were. The larva had a faint yellowish or brownish tinge, while the shell was pale yellowish or golden. The length of the veliger shell was about 0.125 mm. (Fig. 24d-b).

Genus NOTARCHUS

*Notarchus striatus* Quoy and Gaimard

Fig. 25

An egg filament of *Notarchus striatus* was deposited in the laboratory, April 2, 1922. This egg structure, which was light brownish-yellow, was about 10 cm. in length, with a diameter of about 0.7 mm., and thrown into many irregular loops. A break in its length occurred in one place, as if the filament consisted of two parts (Fig. 25a).

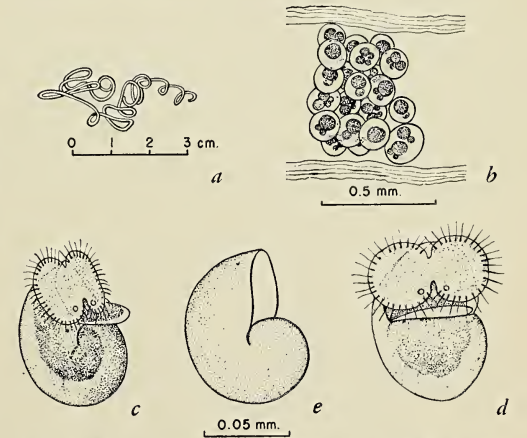


FIG. 25. *Notarchus striatus* Quoy and Gaimard. a, Egg filament; b, magnified section of filament with early cleavage stages; c, d, free-swimming veliger larva; e, shell of free-swimming veliger.

The parchment-like walls of the filament were rather thick and the lumen was tightly packed with ova. The ova, as in other genera of this family, were enclosed in hyaline capsules which usually contained one ovum. Sometimes there were two ova in a capsule, in which case the capsule was of an oblong form, instead of being globular or oval as were those containing only one ovum.

The diameter of the zygote was about 0.07 mm. and its first cleavage was unequal, as in *Tethys grandis*, resulting in one macromere and one micromere. The micromere divided next, equally, then the macromere, also equally, resulting in a stage of two macromeres and two micromeres. The two macromeres remained undivided, while the micromeres rapidly increased in number and formed a cap at the animal pole over the two yolk-laden macromeres at the vegetal pole (Fig. 25*b*).

The free-swimming veliger stage was reached in the short period of 6 days, when the handsome little larvae, whose shells measured but 0.09 mm. in length, emerged from the filament. The parts of the larva enclosed by the shell appeared to be straw colored, while the velum and foot were colorless; the veliger lobes were rather small and rounded, the operculum was broad and rounded and extended well beyond the foot. Otocysts were present, but no eyes. The columellar region of the shell had a light carmine tinge and the suture was of a deep reddish-brown. The rest was pellucid and colorless (Fig. 25*c, d, e*).

### Family HYDATINIDAE

#### Genus HYDATINA

#### *Hydatina amplustre* (Linnaeus)

#### Fig. 26

On the morning of January 4, 1921, I found an egg receptacle in a glass dish with a *Hydatina amplustre*; this also served to

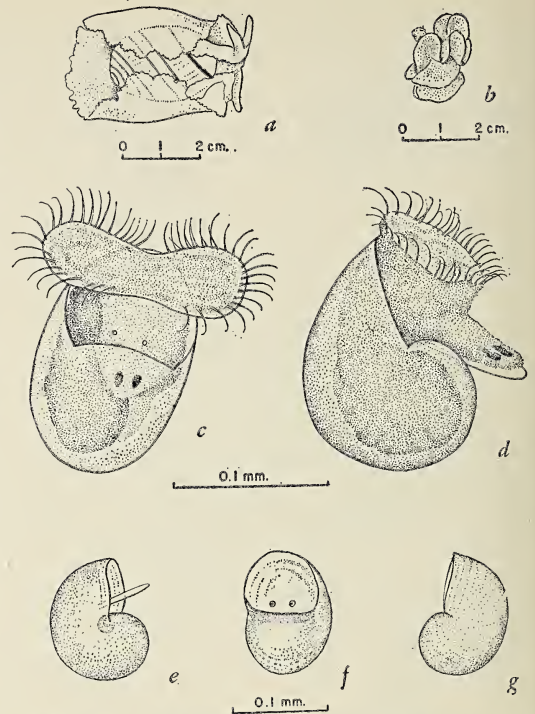


FIG. 26. *Hydatina amplustre* (Linnaeus). *a*, Animal that laid the egg structure; *b*, egg structure; *c, d*, free-swimming veliger: *c*, ventral, *d*, lateral aspects; *e-g*, shell of free-swimming veliger showing operculum and otoliths.

identify several such structures that had been found close to the laboratory. The receptacle was a broad, white ribbon, intensely folded and attached to the surface of the dish with a broad adhesion disk. The ribbon had a width of about 1 centimeter and contained within its walls masses of ova enclosed in hyaline capsules. Development of the embryo was not investigated.

The free-swimming veliger possessed otocysts but not eyes. Two conspicuous elongate dark spots appeared on the ventral side of the foot near the tip, and an operculum was present on the opposite side. The clear, colorless veliger shell measured about 0.125 mm. in length (Fig. 26*a-g*).

#### *Hydatina physis* (Linnaeus)

#### Fig. 27

On November 16, 1922, an egg structure



attached to alga and later identified as that of *Hydatina physis* was found near the aquarium tank. It was about 25 mm. in length, half as wide, and intensely folded, much like that of *H. amplustre*. A single layer of hyaline capsules, each containing five or six embryos, lay between the walls of the structure (Fig. 27*a, b*).

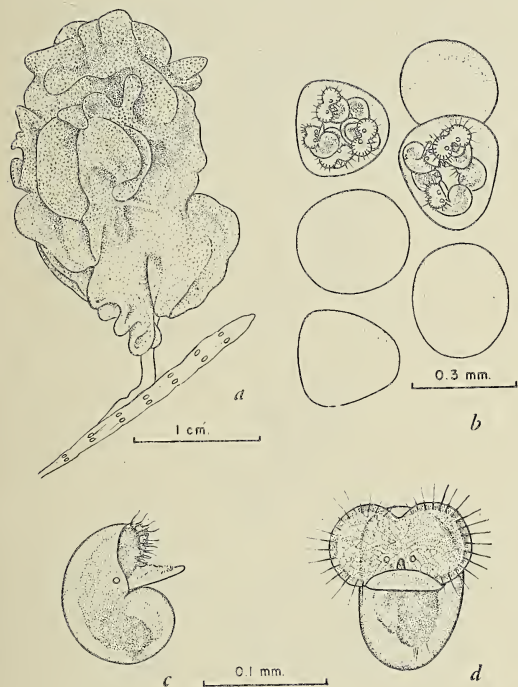


FIG. 27. *Hydatina physis* (Linnaeus). *a*, Egg structure; *b*, egg envelopes with veligers magnified; *c, d*, free-swimming veliger larva: *c*, lateral, and *d*, ventral aspects.

When the structure was obtained the embryos were far along in development. The veliger larva had a faint greenish tinge, and was a little smaller than that of *H. amplustre*. Otocysts and a prominent operculum were present. The shell, measuring 0.11 mm. in length, was colorless, like that of the preceding species. The muscle attaching the larva to the shell was clearly seen (Fig. 27*c, d*).

## Family ACTAEONIDAE

### Genus BULLINA

#### *Bullina scabra solida* Pilsbry

#### Fig. 28

A specimen of *Bullina scabra solida* found at Kahala reef was placed in a dish of water in the laboratory. Two days later, on the morning of March 23, 1921, the mollusk had deposited an egg filament in the dish.

The filament was a short, white, cylindrical tube, arranged in a spiral with one end attached to the bottom of the dish by means of a gelatinous material. The eggs were of varying sizes, quite numerous, and had no orderly arrangement within the structure, each being enclosed within a capsule. The animal was pure white and resembled closely *Hydatina amplustre* (Linnaeus) (Fig. 28*a, b, c*). Development was not observed.

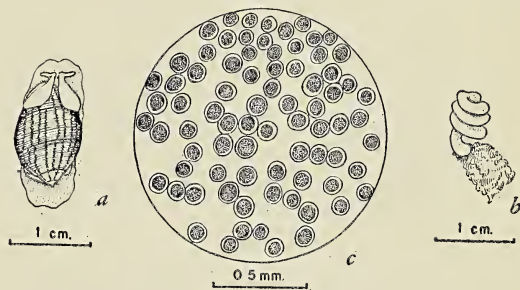


FIG. 28. *Bullina scabra solida* Pilsbry. *a*, Animal that laid the egg mass; *b*, egg filament; *c*, section of coil magnified.

## Family BULLIDAE

### Genus BULLA

#### *Bulla* sp.

#### Fig. 29

On November 22, 1922, two specimens of *Bulla* were brought to the laboratory from the adjacent water. An egg filament was laid by each mollusk the same day. These were comparatively thick cylindrical filaments, 3 cm. in length and 1 mm. in diameter. Each

contained a continuous string of ova wound transversely in circular loops. It could not be determined how the ova adhered to one another in a string. It seemed as if they were enclosed in an invisible gelatinous tube. Each ovum was enclosed in an oval capsule and had a diameter of about 0.06 mm. (Fig. 29*a, b*).

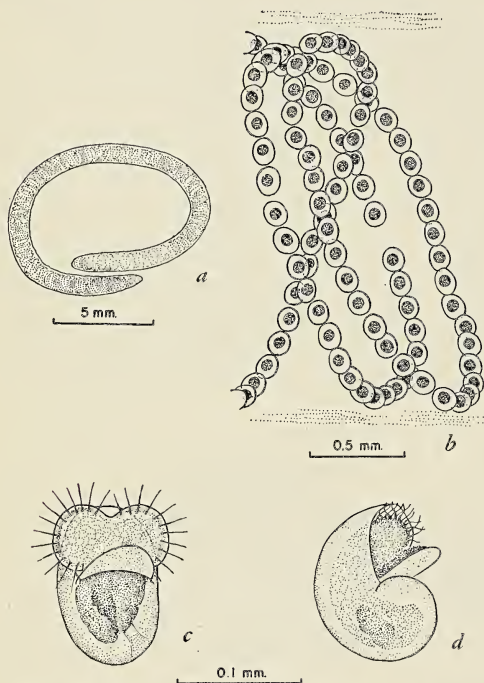


FIG. 29. *Bulla* sp. *a*, Egg filament; *b*, section of filament magnified to show arrangement of ova; *c, d*, free-swimming veliger larva: *c*, ventral, and *d*, partly lateral aspects.

The development of the zygotes was exceedingly rapid, the free-swimming veliger stage being attained in 4 days. The larvae and shells were colorless and neither eyes nor otocysts were present (Fig. 29*c, d*).

#### Family AKERIDAE

#### Genus HAMINOEA

#### *Haminoea crocata* Pease

#### Fig. 30

On March 27, 1923, several specimens of

*Haminoea crocata* were brought to the laboratory from Waianae beach. Several egg filaments were laid by these animals. These filaments resembled those of the *Bulla* in

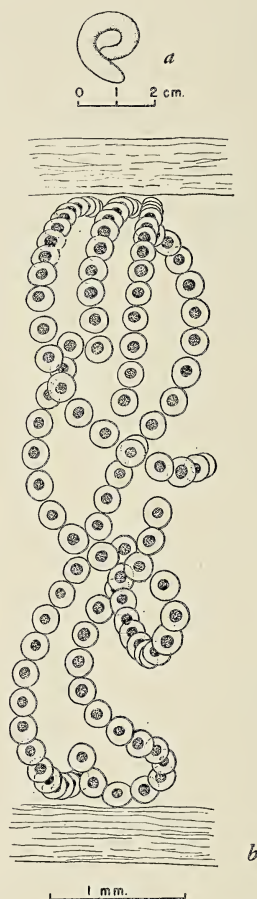


FIG. 30. *Haminoea crocata* Pease. *a*, Egg filament; *b*, section of filament magnified to show arrangement of ova.

their external characters as well as in the arrangement of the ova. The wall of the filament was thicker than in that of *Bulla* and each ovum was enclosed in a spherical capsule, instead of one of oval form as in *Bulla*. The diameter of the ovum was about 0.08 mm. The filament was about 4 cm. in length and about 5 mm. in diameter (Fig. 30*a, b*).



# Family SCAPHANDRIDAE

## Genus ATYS

### *Atys semistriatus* Pease

#### Fig. 31

On August 22, 1921, an egg mass was laid in the laboratory by a specimen of *Atys semistriatus* which had been found near-by.

The egg structure consisted of a globular mass of a soft, clear, gelatinous matrix, about 18 mm. in diameter, in which a thousand or more purple ova were imbedded in a spherical mass and surrounded by a thin layer of the matrix. Each ovum was enclosed in an oval hyaline capsule whose greatest diameter

was about 0.2 mm.; the ovum measured about 0.09 mm. (Fig. 31*a, b*).

Segmentation seemed very rapid, for the eggs, laid in the morning, were found to have attained a many-celled stage in the afternoon. Three macromeres were present at the vegetal pole, and the animal pole was capped with micromeres. About 24 hours later the embryos had become whirling ciliated gastrulas or trochophores.

The embryos did not reach their free-swimming stage, all dying within the matrix, but they reached an advanced veliger stage after 4 days' incubation. The velum was large with long cilia, the foot rather short and broad with a broad, triangular operculum. A rather ample, colorless, and transparent shell enclosed the visceral portion of the larva. A large purplish-red digestive gland could be seen in the region of the stomach, near which a well-defined intestine ran out to the anus beyond the margin of the shell. The eyes consisted of small pigment specks. Otcysts were not seen (Fig. 31*c-f*).

## Family UMBRACULIDAE

### Genus UMBRACULUM

#### *Umbraculum sinicum* (Gmelin)

#### Fig. 32

A specimen of *Umbraculum sinicum*, found near Waialua, Oahu, was brought to the laboratory. On the morning of June 25, 1921, a pink, garland-like egg structure was seen projecting from under its foot.

This structure consisted of a thin ribbon, 15 mm. in width, intensely folded upon itself and attached to the rock by one edge. It was wound three and one-half times around and measured about 12 cm. in diameter (Fig. 32*a*).

The ribbon was closely packed with globular capsules forming one or two layers. These capsules were quite uniform in size, 0.5 mm. in diameter, and each contained about 30 ova. A conservative estimate of the

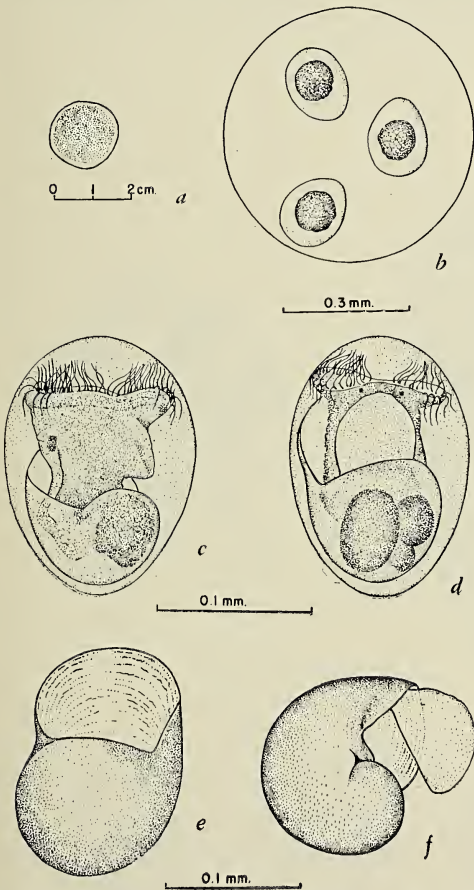


FIG. 31. *Atys semistriata* Pease. *a*, Egg mass; *b*, ova within hyaline capsules, magnified; *c*, *d*, veliger stage before hatching; *e*, *f*, shell of veliger larva with operculum.

number of ova contained in the whole structure gave the figure of 10,206,000 (Fig. 32*b*).

When examined in the morning of the day on which they were found the ova showed no signs of segmentation, but in the afternoon two- and four-cell stages were seen in many capsules, although many of the ova were still unsegmented. Adjoining capsules showed different stages of development, but the embryos in each capsule were usually of the same stage. The ovum was about 0.08 mm. in diameter and the first and second divisions resulted in blastomeres of nearly equal sizes (Fig. 32*c, d, e*). Succeeding stages of cleavage were not observed, but after the third day of incubation when the embryos

had developed minute cilia, movement could be noticed. At the fourth day they showed high activity and the shell was apparently in the process of formation. A large, very conspicuous brown spot had now developed, usually on the right side of the body. After the sixth day of incubation the veliger lobes grew out and the shell covered the body. Neither eyes nor otocysts could be distinguished at this stage.

On the tenth day of incubation a large number of embryos launched upon their free-swimming larval existence. Otocysts, but no eyes, were present, as was a large operculum projecting beyond the tip of the foot and curving upward laterally. The shell was plain, colorless, and translucent (Fig. 32*f, g*).

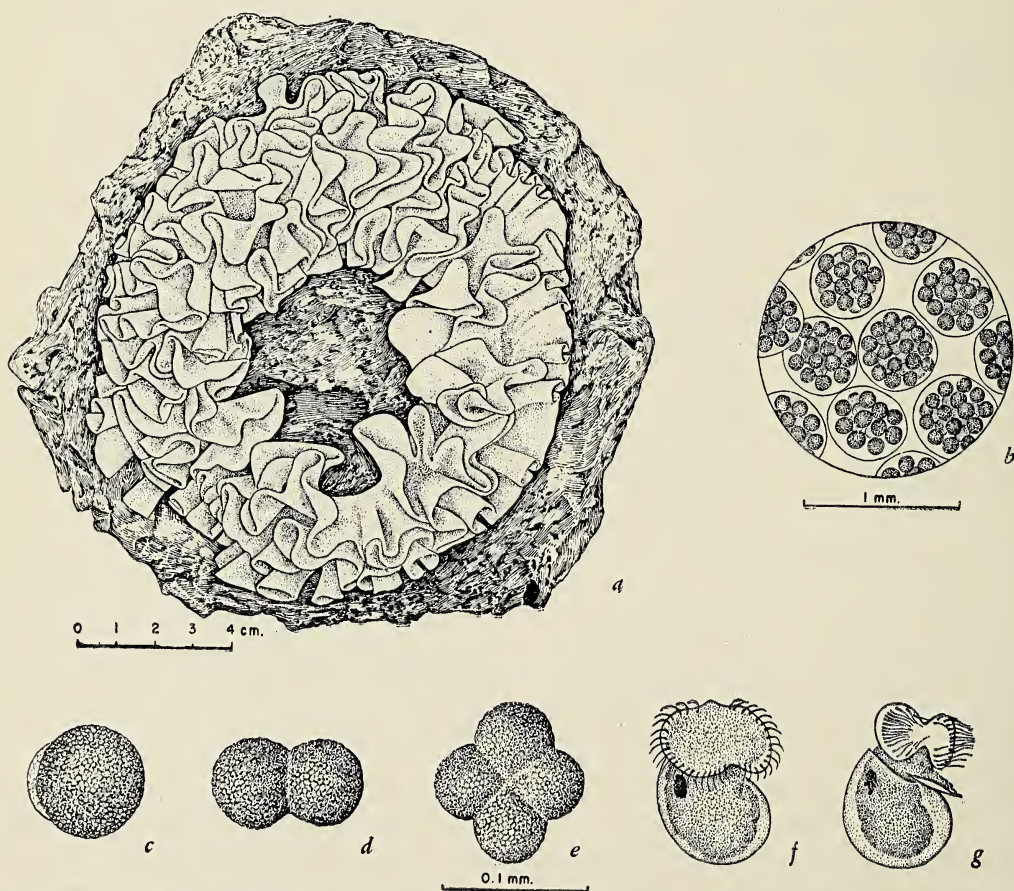


FIG. 32. *Umbraculum sinicum* (Gmelin). *a*, Egg ribbon; *b*, magnified section showing hyaline capsules with ova; *c-e*, cleavage stages; *f*, early veliger; *g*, free-swimming veliger larva.



Family *PLEUROBRANCHIDAE*Genus *PLEUROBRANCHUS**Pleurobranchus* sp.

Fig. 33

On July 25, 1922, a small species of *Pleurobranchus* was found on the windward side of Moku O Loe, Kaneohe Bay, and brought to the laboratory. An egg filament, which for the size of the animal seemed very large, was laid by this mollusk. It was about 18 cm. in length with a diameter of about 4 mm. It was white and transparent and contained what appeared to be a continuous thick-walled tube wound circularly with the filaments in close contact with one another. A single layer of ova, each ovum measuring about 0.08 mm. in diameter and enclosed by a spherical capsule, lay closely packed within this inner tube (Fig. 33*a, b*).

The embryos attained their free-swimming larval stage in 6 days, at which time they had a pair of large, rounded, colorless veliger lobes with conspicuous eye spots, a pointed foot without a visible operculum, otocysts, and a large black pigment spot located near the left side. The viscera were pale greenish-yellow. The shell, which measured 0.125 mm. in length, was clear and colorless (Fig. 33*c-g*).

## Suborder ASCOGLOSSA

Family *PLACOBANCHIDAE*Genus *PLACOBANCHUS**Placobranchus* sp.

Fig. 34

A large number of *Placobranchus* sp. was brought in from Molokai in late February, 1923, and kept in the living state in the laboratory for several months. None of these laid eggs. But a specimen found near the Elk's Club, Waikiki, during March, 1923, deposited a white cylindrical filament, about 19 mm. in length and nearly 1.5 mm. in

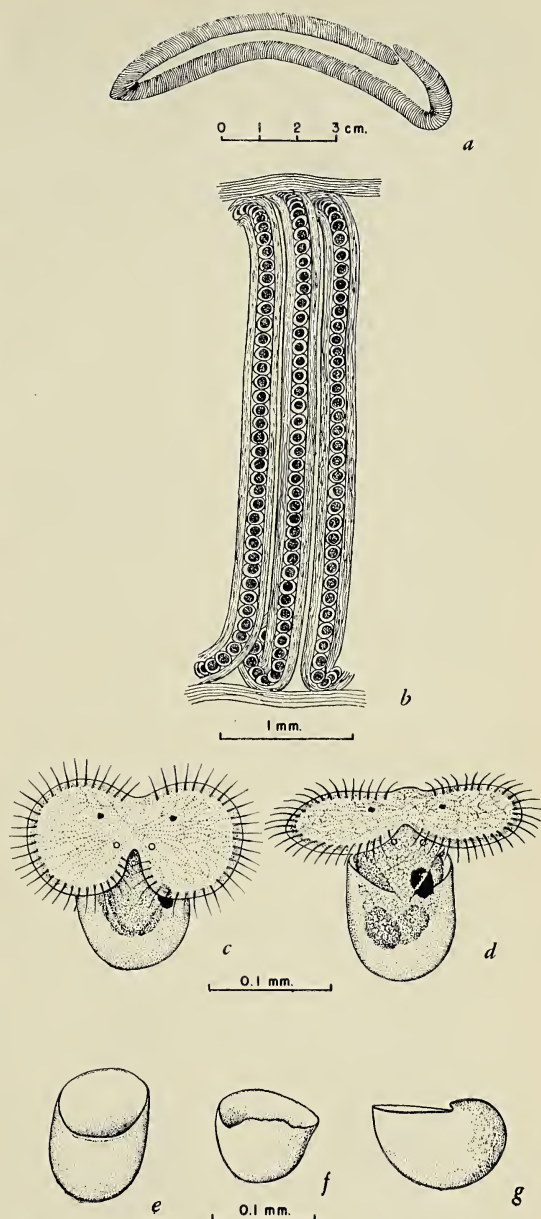


FIG. 33. *Pleurobranchus* sp. *a*, Egg filament; *b*, magnified section of filament showing circularly arranged tubes containing ova; *c, d*, free-swimming veligers; *e-g*, shells of free-swimming veligers.

diameter, which tapered to a point at each end. At the middle of the filament, the ova lay 9 or 10 abreast in cross section; each was enclosed in a globular capsule of about 0.16 mm. in diameter (Fig. 34*a, b*).

The first two cleavages resulted in blastomeres of equal sizes as in the typical gastropod. The embryo reached the free-swimming larval stage in 8 days. Larva and shell were clear and transparent, the operculum large and rounded. Otocysts were present but not eyes. The veliger shell measured 0.14 mm. in length (Fig. 34*c, d*).

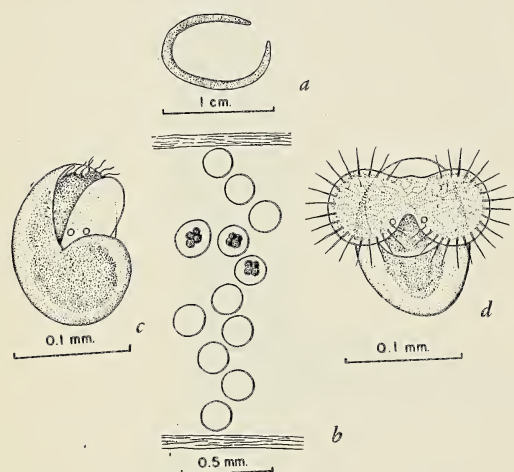


FIG. 34. *Placobranchus* sp. *a*, Egg filament; *b*, magnified section of filament showing 4-cell cleavage stage; *c, d*, free-swimming veliger larva.

## Family ELYSIIDAE

### Genus ELYSIA

#### *Elysia* sp.

#### Fig. 35

Several animals of this genus were found near the laboratory close to shore. An egg filament was deposited in the laboratory by one of them on July 5, 1923. This was a white, cylindrical, twisted filament about 25 mm. in length, closely packed with egg capsules of oval and angular shapes, each containing from two to four ova. The diameter of the ova was about 0.08 mm. (Fig. 35*a, b*).

The free-swimming veliger stage was reached in the short period of 5 days, when the colorless larvae in a pellucid and colorless shell emerged from the coil. The operculum

extended beyond the foot; otocysts were present but not eyes (Fig. 35*c*).

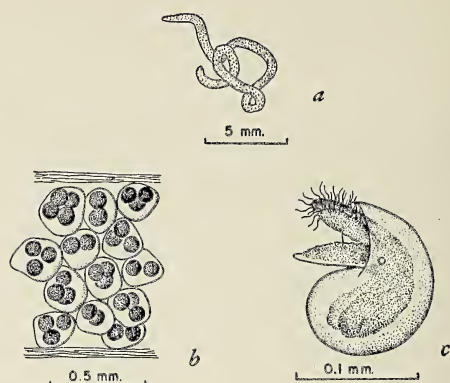


FIG. 35. *Elysia* sp. *a*, Egg filament; *b*, magnified section of filament showing arrangement of ova and hyaline capsules; *c*, free-swimming veliger larva in lateral aspect.

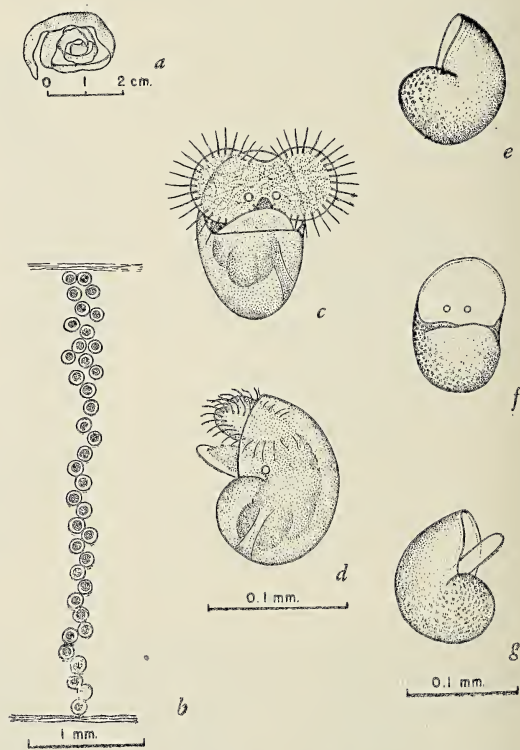


FIG. 36. *Cryptodoris* sp. *a*, Egg ribbon; *b*, magnified section of ribbon showing arrangement of ova; *c, d*, free-swimming veliger larva: *c*, ventral, and *d*, lateral aspects; *e-g*, shell of free-swimming veliger larva with operculum and otocysts.



## Suborder NUDIBRANCHIATA

## Family DORIDIDAE

## Genus CRYPTODORIS

*Cryptodoris* sp.

## Fig. 36

During the night of December 10, 1922, an egg ribbon was deposited in the laboratory by an animal of the genus *Cryptodoris*. This was a bright yellow ribbon of three volutions. It was about 4 mm. in width and filled with globular egg capsules, each containing an ovum. There were about 30 ova abreast in cross section. The ova were about 0.06 mm. in diameter (Fig. 36*a, b*).

As the embryos developed, the ribbon turned bright copper color and the free-swimming veliger stage was attained in about 10 days. The shell at this stage was about 0.12 mm. in length and of a bright copper color on the apical side of the columella. The veliger lobes were round with long cilia and the operculum prominent. No eyes were present but otocysts were. A larval muscle was clearly seen (Fig. 36*c-g*).

## Genus GLOSSODORIS

*Glossodoris* sp.

## Fig. 37

In March, 1923, two animals of this genus were brought to the laboratory from Waianae. An egg ribbon was deposited by one of them during the night of March 17, 1923. This consisted of a flat white band about 4 mm. in length and of one volution. About 10 ova were seen abreast in cross section, each enclosed in a spherical capsule about 0.14 mm. in diameter (Fig. 37*a, b*).

## Family HEXABRANCHIDAE

## Genus HEXABRANCHUS

*Hexabranhus* sp.

## Fig. 38

On May 21, 1923, an egg structure was

deposited in the laboratory by this beautiful nudibranch, several specimens of which had been kept living for months in aquarium jars.

A few days after the first egg structure was found, a second and larger one with one volution more than the first was deposited by the mollusk. A study was made of the first structure. This was a bright scarlet to orange,

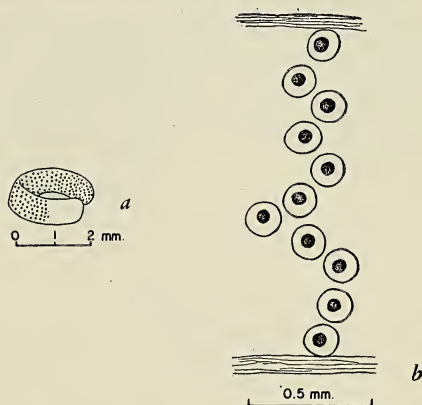


FIG. 37. *Glossodoris* sp. *a*, Egg ribbon; *b*, magnified section of ribbon showing arrangement of ova.

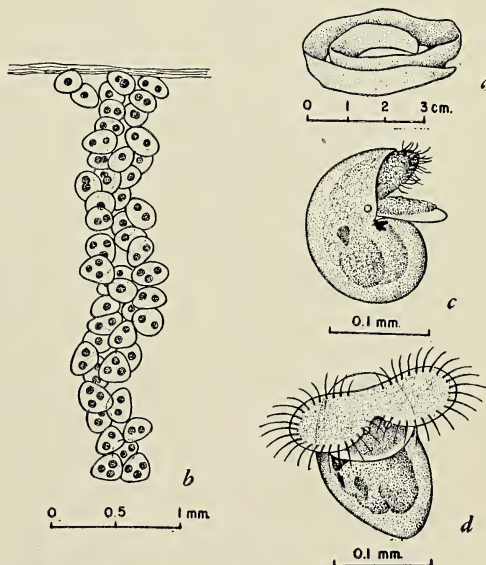


FIG. 38. *Hexabranhus* sp. *a*, egg ribbon; *b*, magnified section of ribbon showing arrangement of hyaline capsules and ova; *c, d*, free-swimming veliger larva: *c*, lateral, and *d*, ventral aspects.

flat ribbon of two volutions, about 14 cm. in length and 6 mm. in width. The structure was closely packed with oval and triangular egg cases containing from one to three ova each. The ova were about 0.06 mm. in diameter (Fig. 38*a, b*).

The free-swimming stage was attained in 9 days, when a pale brownish larva emerged. On the right side of the body of the larva was an irregular black pigment spot and near it another of dark orange. Otocysts were present, but not eyes. A broad operculum and a clear and pellucid shell were present (Fig. 38*c, d*).

### Family AEOLIDIIDAE

#### Genus AEOLIDIA

#### *Aeolidia* sp.

#### Fig. 39

During the month of April, 1922, a number of egg structures were deposited on a rock in the laboratory by a species of *Aeolidia*. They were flat, bright yellow ribbons about 18 mm. long and 2 mm. wide, of one volutions which was so close that the inner margins, by which the mass was attached, almost touched (Fig. 39*a, b*). The ova were strung out in single rows within transverse gelatinous tubes which radiated from the inner margin of the ribbon. A row contained an average of 15 ova. The spaces between the transverse tubes toward the outer margin also contained ova (Fig. 39*c*). The ova, which measured about 0.17 mm. in diameter, were contained singly in oval capsules.

This is the most prolific mollusk in point of numbers of egg structures yet observed. Nine ribbons were deposited by the same animal within 12 days, one each day for several days. Two more mollusks of this species were brought in from near the Elk's Club, Waikiki. Both animals were on a living coral head, *Porites compressa*, to which were attached half a dozen or more egg ribbons.

During 10 days of captivity the number of ribbons deposited by them had increased to 30. The ribbons were all of a very pale yellow and nearly all of them were larger than those of the first lot, most of them being twice as great in diameter.

The eggs of all the ribbons seemed to develop and the free-swimming stage was reached in 6 days. The eyespots in this larva were large and prominent, as were foot and

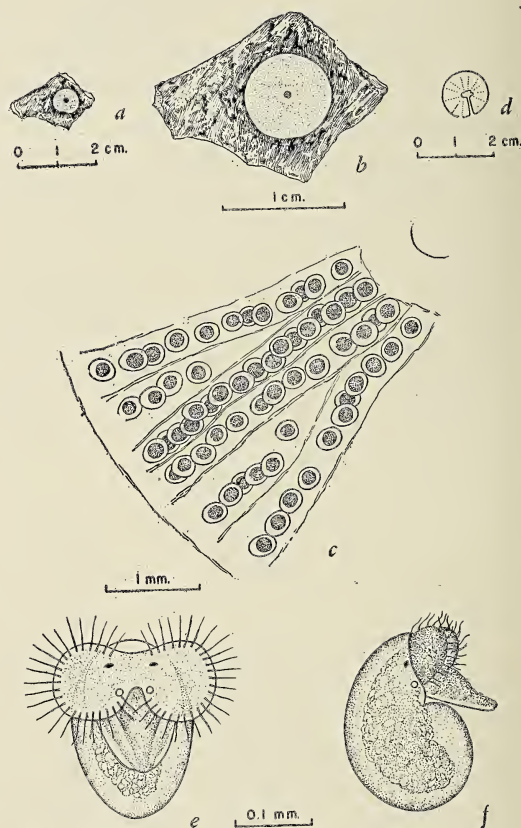


FIG. 39. *Aeolidia* sp. *a*, Egg ribbon; *b*, ribbon enlarged; *c*, magnified section of ribbon showing arrangement of ova; *d*, egg ribbon laid by another individual; *e, f*, free-swimming veliger larva: *e*, ventral, and *f*, lateral aspects.

operculum. The viscera had a marked yellowish tinge, but the foot and velum were almost colorless. The shell, measuring 0.225 mm. in length, is pellucid and colorless (Fig. 39*e, f*).



Family FIMBRIIDAE

Genus MELIBE

*Melibe pilosa* Pease

Fig. 40

Early in February, 1922, some egg structures were deposited in the laboratory by specimens of *Melibe pilosa* found close to the laboratory pier. The egg structure consisted of a very thin, broad, white ribbon, greatly folded, and spirally wound several turns, united by the inner edges, by which it was attached to a rock or other object (Fig. 40a). Transversely arranged within the capsular wall, and closely filling the space, was a cylindrical tube packed with egg cases arranged in a single row. These egg cases, or hyaline envelopes, had the shape of a hen's egg and measured about 0.17 mm. by 0.25 mm. Each case contained one ovum which had an average diameter of 0.125 mm. (Fig. 40b).

Development of the embryo was not in-

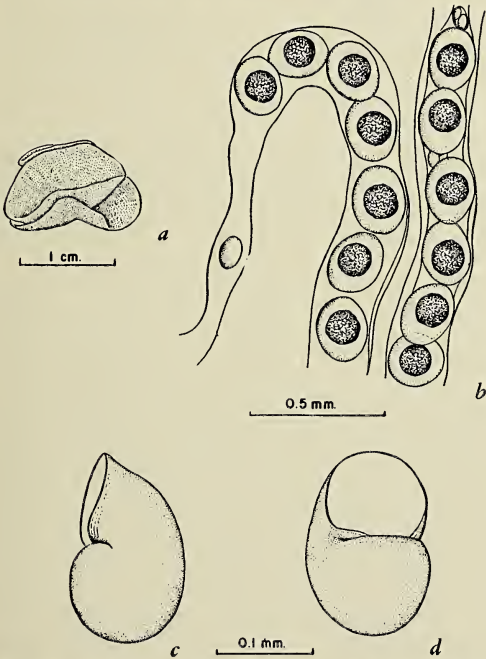


FIG. 40. *Melibe pilosa* Pease. a, Egg ribbon; b, magnified section of ribbon showing ova in hyaline capsules contained in tubes; c, d, shell of free-swimming veliger.

vestigated, but a study of the veliger shell was made. This was elongate, pellucid and colorless, about 0.2 mm. in length (Fig. 40c, d).

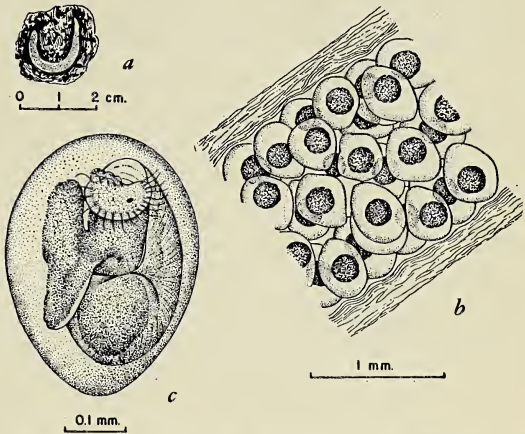


FIG. 41. *Siphonaria normalis omara* Reeve. a, Egg ribbon; b, magnified section of ribbon showing compact masses of hyaline capsules with ova; c, unhatched veliger stage.

Order PULMONATA  
Family SIPHONARIIDAE

Genus SIPHONARIA

*Siphonaria normalis omara* Reeve

Fig. 41

On September 9, 1923, a specimen of *Siphonaria* deposited an egg structure in the laboratory, several of the animals having been brought in from the near-by sea wall. The egg structure was a somewhat thickened colorless ribbon, arranged in a half circle which measured about 3 cm. in length and 2 mm. in width. The walls of the ribbon were very thick and fibrous, and the eggs were closely packed in two layers. A rather ovoid hyaline envelope surrounded each ovum. This envelope measured about 0.485 mm. in length and 0.34 mm. in width; the diameter of the ova was about 0.19 mm. (Fig. 41a, b).

Steps in development were not observed, but a study of the embryo when it had reached the veliger stage was made. The color of the animal was pale greenish, while that of the

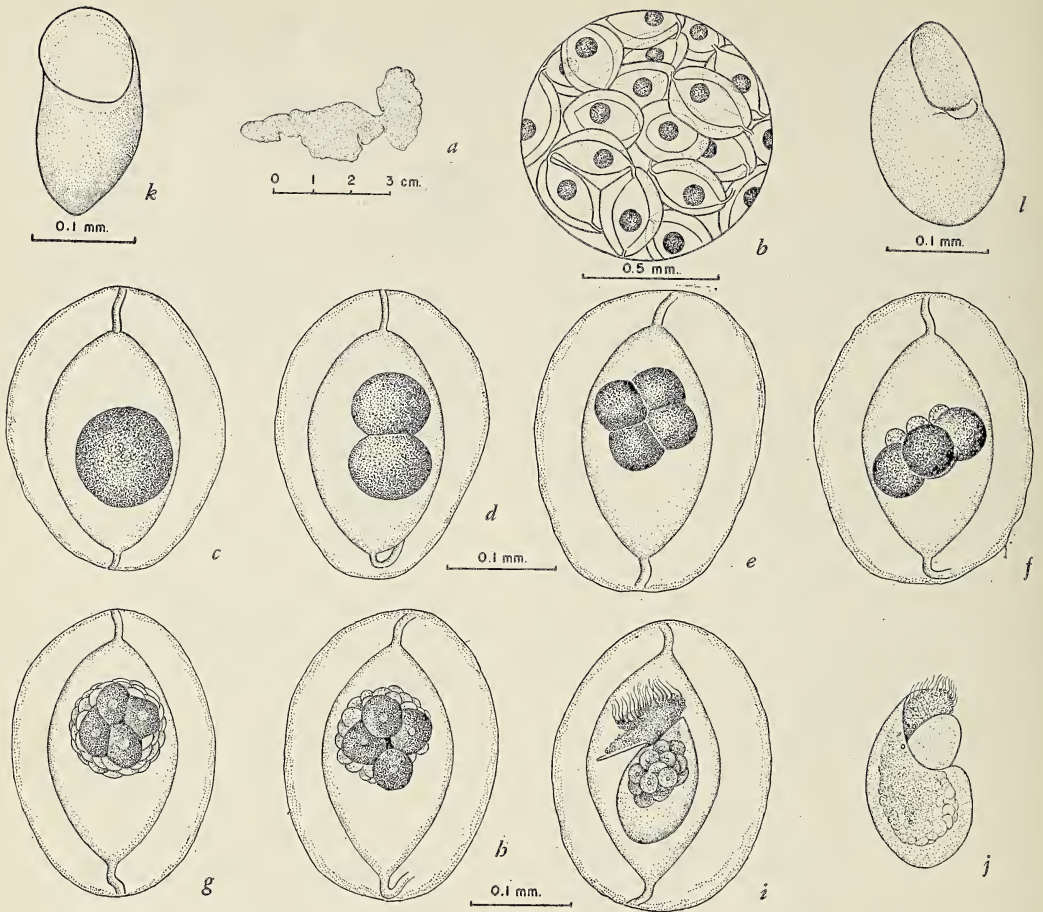


FIG. 42. *Peronia* sp. *a*, Egg structure; *b*, magnified section of egg structure showing a double capsular enclosure for ova; *c*-*g*, cleavage stages; *h*, gastrula?; *i*, early veliger with extremely large endodermal cells; *j*, free-swimming veliger; *k*, *l*, shell of free-swimming veliger.

shell was brown. Eyes were present. The foot was large with a conspicuous operculum. The shell was about 0.33 mm. in length (Fig. 41*c*). The embryos all died, so the free-swimming stage was not observed.

### Family ONCHIDIIDAE

#### Genus PERONIA

#### *Peronia* sp.

#### Fig. 42

Early in September, 1921, a number of specimens of *Peronia* were gathered from crevices in the sea wall near the laboratory.

These were placed in a jar with running water, from which they soon escaped, being air-breathers, and scattered all over the aquarium tables. Some crawled into dark, wet corners of wooden boxes, where they seemed to thrive. Some lived thus for months in the laboratory. It is obvious that this mollusk cannot live under water, while, on the other hand, it needs to be kept wet constantly with sea water. It has been found at Kaena Point and Black Point on the shore rocks above high tide level and where only the spray could reach it. A large number of these mollusks were found at Kawaihoa, Oahu, during June.



Eggs were deposited in the laboratory by one of these animals on September 3, 1921. Since that time they have often been obtained from other individuals. The egg structure was a lemon-yellow, tough, gelatinous mass with irregular outlines, pasted flatly onto any surface. The ova were closely packed throughout the whole structure and each was enclosed within a double capsule. The diameter of the ovum was about 0.08 mm. The lesser diameter of the inner capsule, which was of a regular oval or oblong form, was 0.14 mm., its greater diameter being 0.22 mm. The lesser diameter of the outer capsule, which was of an irregular oval or somewhat baggy shape, was 0.2 mm.; its greater diameter was about 0.28 mm.

The relations of the capsules to one another appeared to be as follows: from each end of the inner capsule sprang a slender tube or thread which united with another inner capsule, penetrating the outer capsule in doing so, forming thus a continuous, closely united string of egg capsules thrown promiscuously together (Fig. 42*a, b*).

Cleavage of the zygotes commenced the same day they were laid, the 4-cell stage being reached during the afternoon. The first two divisions were equal and the third resulted in four micromeres at the animal pole of the macromeres; hence it was typical of gastropod cleavage (Fig. 42*c-f*).

A many-celled, or morula, stage was reached after 24 hours. The four undivided macromeres showed up distinctly at the vegetal pole, their nuclei appearing as clear globules. From the animal pole numerous micromeres extended beyond the equator. Soon a contraction of each of the four undivided macromeres took place, rounding off their former angular outlines and leaving an opening between them (the gastropore?) at the vegetal pole. Cleavage of the macromeres seemed greatly retarded, probably due to the obstruction of the yolk. This is typical epibolic gastrulation (Fig. 42*g, b*).

The extremely slow division of the macromeres, or endodermal cells, remained a characteristic feature of the development of this mollusk. Even when the veliger stage was reached, these cells appeared as a large cluster, each with a distinct, rounded outline and a clear central nucleus (Fig. 42*i*).

The free-swimming stage was attained after 9 days of incubation, when a veliger larva appeared within an elongate, clear, colorless shell which was nearly bilaterally symmetrical. The foot bore a broad, anteriorly rounded operculum. Eyes, as well as otocysts, were present. The endodermal cells, still large and conspicuous, were of a bright yellow or brassy color (Fig. 42*j, k, l*).

## CONCLUSIONS

### Pelagic Stage and Distribution

Of all the species studied—those included in this paper and others to be reported upon later—41 attained the veliger stage. Of these, 40 were found to have a pelagic stage, thus giving the high figure of 97.5 per cent pelagic or free-swimming larvae.

This seems remarkable in view of the fact that Thorson (1940) reports 75 per cent from the Iranian Gulf as the highest percentage in a list prepared by him, while next highest he quotes Risbec from New Caledonia with 57 per cent. He shows a general increase in pelagic larvae from the colder to the warmer waters, beginning with none in East Greenland and ending with 75 per cent for the Iranian Gulf.

It appears that temperature is of much importance in determining the pelagic stage, but there seem to be other controlling factors also. When the isolation of the Hawaiian Islands caused by their vast ocean barriers is considered, it may be inferred that its molluscan population must have depended upon a pelagic or free-swimming stage of sufficient duration to enable the larvae to be carried by currents from islands in the Pacific support-

ing a gastropod fauna similar to the one of Hawaii. Such faunas are found in Micronesia. We may then postulate that ocean currents from that region were the source of distribution of the marine gastropods of Hawaii. The veliger larva could be carried east by the North Equatorial Current, which, along its course, might yield parts of its planktonic cargo to the westward-flowing Japan Current to be carried by it to the Hawaiian Archipelago. If this be the chief, or only, method of deriving our marine gastropod fauna, we must at once recognize the importance of a long free-swimming existence to the successful migration over vast ocean barriers.

#### Phylogenetic Significance of Veliger Shell

The great dissimilarity between the veliger larva and the adult gastropod may have its explanation on the basis of adaptation on the one hand and heredity on the other. To structures that have developed as adaptive measures in the larva is applied the term ceno-genetic in contradistinction to the term palin-genetic, which deals with characters of ancestral significance, thus throwing light upon the evolutionary history of the organism.

The ciliated veliger lobes by means of which the larva leads its pelagic existence appear important to the distribution of numerous species and might therefore be classed as an adaptation. We can, however, conceive of a minute gastropod ancestor, which, like the wheel animalcule (Rotifera), was provided with ciliated lobes that served both for locomotion and food getting before it developed its protective shell. Concerning the veliger shell it will be noted that it was present in the opisthobranch larva as well as in that of the prosobranch, even in groups where it is entirely lacking in the adult animal. In addition to the veliger shell an operculum was found in all but two species, *Conus hebraeus* and *Pleurobranchus* sp. I have failed to see any service of the operculum to the

veliger larva. During the active existence of the larva, the foot with its operculum was fully extended, and only when a larva sank to the bottom to die was the operculum seen to close the aperture to the shell.

Veliger larva and shell both show a close approach to a bilateral symmetry, which in later development is lost by coil formations. It appears that both the veliger larva and the shell with the operculum have a palin-genetic significance in which the swimming apparatus, the veliger lobes, have been retained owing to their functional value, coming to overlap in time, as it were, a later ancestral structure, the shell.

Supportive evidence for such a contention may be found in a comparison of the veliger shell with some of the fossil gastropods of the early Paleozoic era, Cambrian and Ordovician, which show simple shells of bilateral symmetry and from which might be derived the divergent groups, viz., the coiled snail on the one hand and the naked slug on the other.

One may readily observe a similarity in the structure of spawn as well as in larval peculiarity in species of the same genus and more so, perhaps, if the species are closely related. Such a condition may then parallel to a large extent the taxonomic position assigned to the adult forms and, therefore, be of taxonomic value.

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## Vespoidea of Micronesia. 3<sup>1</sup>

KEIZÔ YASUMATSU<sup>2</sup>

IN 1938 Professor Teiso Esaki recorded the occurrence of a mutillid wasp in Micronesia for the first time. This handsome mutillid was identified by him as *Timulla (Trogaspidia) albertisi* (André, 1896), although he felt some suspicion with respect to the identity of certain details of the pubescence. In the spring of 1949 Professor Esaki requested me to re-examine this mutillid specimen. After a careful study of the specimen, as well as of the descriptions of some related species, I came to the conclusion that the specimen represents a new species, as pointed out by Dr. Krombein (Hawaii. Ent. Soc., Proc. 13, 1949).

### *Timulla (Trogaspidia) esakii* sp. nov.

- 1938 *Timulla (Trogaspidia) albertisi* Esaki (nec André), *Annot. Zool. Jap.* 17: 431-432, ♀.  
1949 *Timulla* sp., Krombein, *Hawaii. Ent. Soc., Proc.* 13: 369, 375-376.

Female. 10.5 mm. long. Head, thorax, and abdomen entirely black. Median portion of mandibles, antennal tubercles, and apex of antennal scapes ferruginous. Front clothed with sparse, erect, pale pubescence and somewhat dense, recumbent, ferruginous pubescence. Vertex covered with thick, appressed, pale or somewhat ferruginous pubescence, but not distinctly "échancrée en arc en avant" as in *albertisi*. Genae with somewhat thick, recumbent, pale pubescence. Mandibles slender, edentate at apex and with a small tooth

on inner margin near apex. Clypeus elevated posteriorly, elevated margin arcuate and with a very small tubercle just at the middle of the margin, median longitudinal line of elevated area ridged; anterior margin of clypeus straight. Antennal scape almost impunctate; third antennal segment about twice as long as fourth. Antennal scrobes carinate above. Malar space about as long as wide. Front, vertex, and genae with moderate, dense, confluent punctures. Apical half of malar space almost impunctate, but basal half minutely wrinkled. Relative width of head and thorax (mesonotum) about 37:32. Dorsum of thorax clothed with sparse, erect, pale pubescence and sparse, recumbent, somewhat ferruginous pubescence. Pale pubescence on dorsum of anterior portion of pronotum thick and erect. Posterior face of propodeum with somewhat dense, long, erect, pale pubescence. Pleural area with pale or whitish micropubescence. Dorsum of thorax with moderately large, dense, confluent punctures; humeral angles angulate but inconspicuous; pronotum slightly wider posteriorly than anteriorly; mesonotum only faintly narrower than pronotum; lateral margins parallel and crenulate; scutellar scale present, distinct and slightly raised; lateral margins of posterior face of propodeum denticulate. Anterior margin of propleurae defined by distinct carina; all of pleural areas, including sides of propodeum, impunctate. Abdominal tergites II, IV, and V covered with ferruginous black, velvety pubescence; laterobasal areas of second tergite and basal and apical margins of fourth and fifth tergites without such velvety pubescence; second tergite with a pair of large, subcircular, anterior spots separated by about their own transverse diameter; third tergite

<sup>1</sup>Results of Professor T. Esaki's Micronesia Expeditions, 1936-1940, No. 79.

<sup>2</sup>Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, Japan. Manuscript received July 21, 1949.



with a broad, complete band of dense, appressed, golden pubescence. Pubescence on posterior margin of second tergite somewhat ferruginous at middle and pale laterally. A very small tuft-like golden pubescence is recognizable at middle of posterior margin of second tergite. First tergite and anterior portion of second covered with rather dense, erect, long, pale pubescence. Pygidium with dense, erect, long, pale pubescence only at sides. Posterior margin of second to fourth sternites with rather dense, erect, long, pale pubescence. First tergite with dense, moderate punctures, posteriorly the punctures close and confluent; second tergite with moderate, well-separated punctures. Tergites III to V with small, well-separated punctures. Pygidium minutely, longitudinally striate except apically and with close, small, confluent punctures at sides. First sternite with a prominent, median, longitudinal carina, in profile appearing roundly emarginate; second sternite with sparse, moderate punctures except the posterior margin with small, close punctures; sternites III to V with sparse, moderately small punctures, denser at the posterior margin of each; hypopygium with moderately small, close punctures. Legs entirely

black, sparsely covered with pale pubescence; calcaria pale.

*Holotype*: ♀, Palau Islands—Ashiasu, Peliliou Island, 23, II, 1938, Professor Esaki leg., preserved in the collection of the Entomological Laboratory, Kyushu University.

*Habitat*: Micronesia—Palau Islands.

This new species is closely related to *Timulla* (*Trogaspidia*) *albertisi* (André, 1896) from New Guinea, but the latter is quite distinct from this species in the following points: "Tête avec des soies noires éparses sur le front; vertex largement recouvert d'une bande de pubescence fine, serée, d'un jaune d'or soyeux, échancrée en arc en avant. Thorax hérissé de soies noires sur le dos . . . et recouvert sur les flancs d'une pubescence jaunâtre . . ." (E. André, 1896, *Études sur les Mutillides existant dans les collections du Musée Civique de Gênes. Ann. Mus. Civ. Stor. Nat. Genova* II, 17: 70–71).

This species is known at present only from the unique female described above. It is named in honor of Professor Esaki of the Kyushu University, who first discovered the mutillid wasp in Micronesia.

I wish to express my sincere thanks to Professor Esaki for his generosity in placing the material at my disposal.

# Contributions to the Knowledge of the Pacific Species of *Antithamnion* and Related Algae<sup>1</sup>

JUN TOKIDA AND TADAOKI INABA<sup>2</sup>

THE JUNIOR AUTHOR, T. Inaba, expert of the Fisheries Department of Fukui prefectural government, was able to make collections of marine algae along the coast of Bōsō Peninsula lying southeast of Tokyo Bay, during the time he was engaged as a teacher in the Awa Suisan-Gakkō (School of Fisheries) in Tateyama City, Chiba prefecture. This is a most interesting coast for phycologists, offering many kinds of temperate-zone seaweeds, and, of course, has already been frequently botanized by many other persons. Nevertheless, further effort in searching there for new or rare species seems to be quite promising in view of the fruitfulness of the junior author's collections, especially those made in the spring of 1944. Partial results of our studies on the species of *Antithamnion* and its allied genera which were thus discovered are reported here.

The text figures 1*a*, 1*b*, 4, 5*a*, 5*b*, and 10*a* are reproduced from the drawings by Inaba, while the rest are from those of Tokida. Figures 6 and 8 are reproduced from photograph negatives obtained by projecting on bromide papers with an enlarging camera the images of the specimens mounted in glycerine on a glass slide.

It will not be superfluous to give here an explanation of the technical terms used in our descriptions. By the terms "ramus" or "branch," "pinna," "pinnula," and "ramulus,"

we intend to express the different orders of the successive branching system in *Antithamnion* and its allied genera. The ramus, being provided with a meristem at its top, is the direct offshoot of the main axis of the frond and bears pinnae. Pinnae, in *Antithamnion*, are usually opposite or sometimes whorled offshoots on each segment of the main and branch axes, simple or divided, bearing, in the latter case, pinnulae. Pinnulae, in *Antithamnion*, are opposite, alternate, or secund on the pinnae, arising usually singly or rarely by pairs from some segments of the axis of pinnae. Ramuli are usually simple offshoots arising singly from some segments of the axis of pinnulae. By "ultimate ramuli," however, we do not always mean ramuli but sometimes mean either pinnulae or pinnae according to the extent of intricacy of the branching system.

The senior author wishes to acknowledge his indebtedness to Mme. Valerie May for her kindness in sending him a fragment of an authentic specimen of *Acrothamnion pulchellum* J. Ag., and to Dr. E. Yale Dawson of the University of Southern California for his kindness in sparing from his library valuable publications helpful for the present study.

*Antithamnion basisporum* Tokida and Inaba,  
sp. nov.

Figs. 1*a*-*c*; 2*a*-*d*

Fronde sparse ramosa et opposita pinnata; axibus principalibus inferne repentibus, rhizoidibus brevissimis et simplicibus, 16-26  $\mu$  crassis, a cellulis basalibus pinnarum emit-

<sup>1</sup>The expense of the present study has been partly defrayed from the subsidy granted by the Hattori Hōkō Kai, and from the fund for scientific research granted by the Ministry of Education.

<sup>2</sup>Botanical Laboratory, Department of Fisheries, Faculty of Agriculture, Hokkaido University, Sapporo, Japan. Manuscript received April 26, 1949.



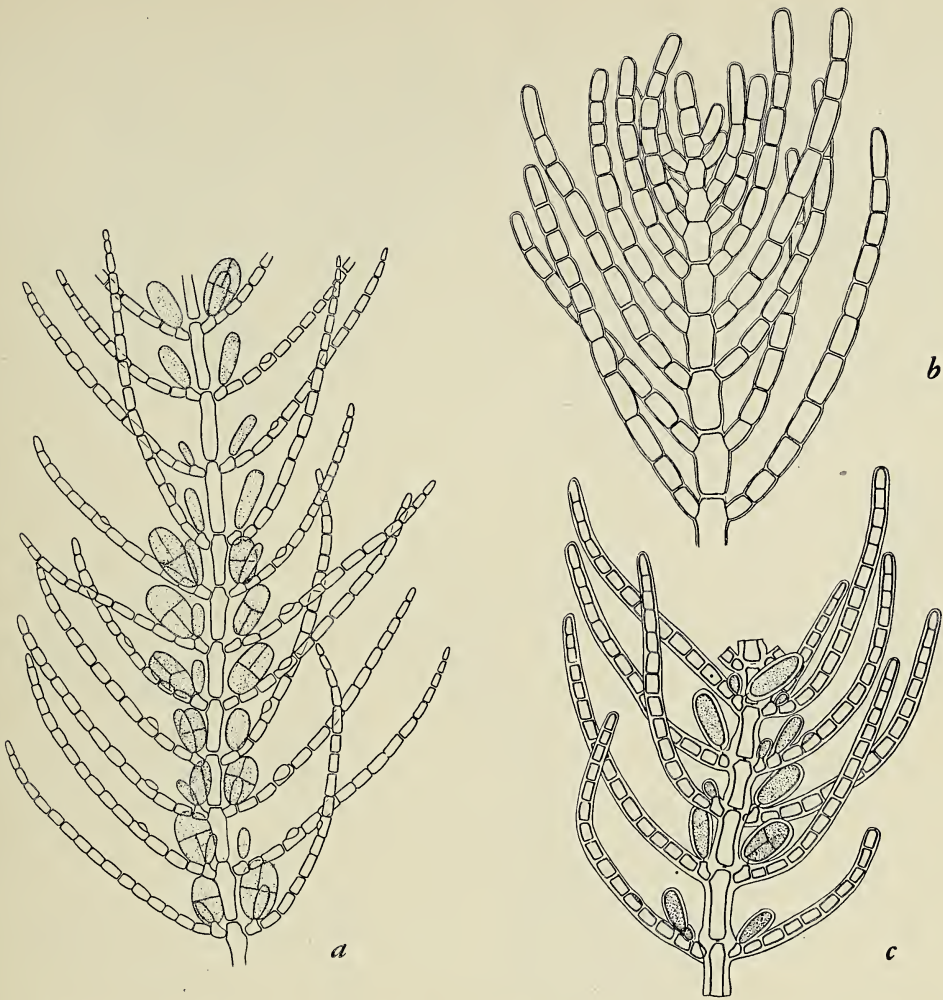


FIG. 1. *Antithamnion basisporum* Tokida and Inaba, sp. nov.: *a*, middle portion of a main branch, showing tetrasporangia and gland cells; *b*, apical portion of a main branch; *c*, part of a branch, showing that two of the pinnae bear a sporangium on each of two lowest cells, and that one pinna bears on its lowest cell a pinnula together with a sporangium. *a* and *c*,  $\times 150$ ; *b*,  $\times 350$ .

tentibus adfixis, superne erectis et ca. 2 mm. altis; ramis in plerisque a cellulis basalibus pinnae vel raro a cellulis axialibus ramorum ipsis emittentibus, usque ad 20–32  $\mu$  crassis, cellulis diametro 1–4-plo longioribus; pinnis simplicibus vel raro semel divisis, apice rotundatis, 7–14 (–16)-cellularibus, usque ad 14  $\mu$  crassis, cellulis diametro 1–3-plo longioribus, cellulis glandulinis supra unam cellulam lateraliter sitis ornatis; chromatophoris paucis, taeniatis; tetrasporangiis in cel-

lulis basalibus pinnae sessilibus, 28–38  $\mu \times 56$ –64  $\mu$ , cruciatim divisis; spermatangiis et ramulis carpogonatis ignotis.

Frond sparsely branched and oppositely pinnate; main axis creeping below, attached to the substratum by means of short, simple rhizoids, 16–26  $\mu$  diam., arising from the basal cells of pinnae, erect above, ca. 2 mm. high; branches usually produced from the basal cells of pinnae or rarely from the axial cells of the main branch itself, up to 20–32  $\mu$

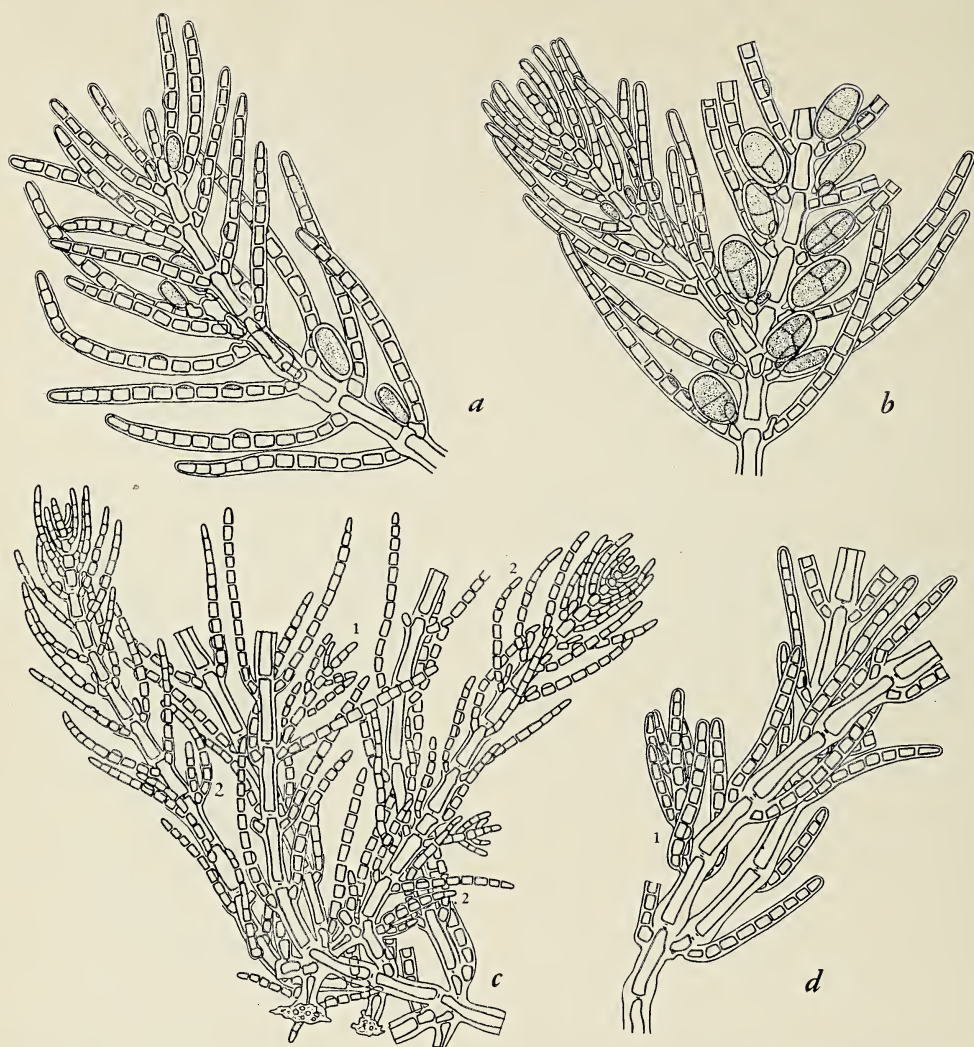


FIG. 2. *Antithamnion basisporum* Tokida and Inaba, sp. nov.: *a* and *b*, mode of branching in the upper portion of a frond; *c* and *d*, mode of branching in the lower portion of a frond and young branches arising from the lowest cell of the pinna (1); *c*, rhizoidal filaments: three pinnae which bear on their lowest cells a short pinnula (2), and the branch apices, are also shown. *a*, *b*, and *d*,  $\times 150$ ; *c*,  $\times 137$ .

diam., with cells 1–4 diameters long; pinnae simple or rarely once divided, rounded at apices, 7–14 (–16)-celled, up to  $14\ \mu$  diam., with cells 1–3 diameters long, provided with gland cells which sit singly on the upper lateral side of the cell; chromatophores a few bands; tetraspores sessile on the basal cells of pinnae,  $28\text{--}38\ \mu \times 56\text{--}64\ \mu$ , cruciately divided; sexual reproductive organs unknown.

*Japanese name:* NIRETSU-KASANEKUSA

(nom. nov.).

*Type:* Growing on pebbles, Mera, Prov. Bōshū. *T. Inaba* 401, Apr. 10, 1944 (Herbarium, Dept. Fish., Hokkaido Univ.).

This species of *Antithamnion* is one of those bearing simple pinnae. It differs from many of the allied species, e.g., *A. glanduliferum* Kylin, *A. pacificum* (Harv.) Kylin, *A. Gardneri* De Toni, etc., in having one to two tetrasporangia on the lowermost cell of



the pinnae, while it resembles in this respect *A. Mibarai* Tokida (Tokida, 1942: 90, text figs. 5 and 6). The last-mentioned species differs from our new species in having tetrasporangia not only on the lowermost cell but also on two succeeding cells. The most striking character of the present species seems to be that the tetrasporangia are arranged in a longitudinal row along each side of the axis of branches. The cell next to the lowermost cell of pinnae rarely bears a sporangium. In the lower part of the frond a branch is produced by the basal cell of a pinna, and sometimes it lacks an adaxial pinna on its lowermost cell, while in the upper part of the frond a branch is formed directly from the axial cell of the main branch and is provided with a short basal cell which bears no pinna but occasionally bears a sporangium. The cell next to the basal cell of a branch in the upper part of the frond sometimes lacks an adaxial pinna. The pinnae are as a rule simple, but rarely they bear a small pinnula on their lowermost cell. A pinnula of this kind is probably nothing but the beginning of a branch.

*Antithamnion cristirbizophorum*

Tokida and Inaba, sp. nov.

Figs. 3a–d, 4

Fronde ca. 5 mm. alta, sparse ramosa et opposita pinnata, repenti, rhizoidibus cristatis a cellulis basalibus pinnarum emittentibus ramis aliae algae ut *Ceramii* sp. et *Gelidii subcostati* adfixa; ramis a cellulis basalibus pinnarum emittentibus, usque ad 120–150  $\mu$  crassis, inferne cellulis diametro 1.5–3.5-plo, superne 0.5–2-plo, longioribus, cellulis apicalibus 8  $\mu$  crassis; pinnis lanceolatis, cellulis ad septa leve constrictis, cellulis basalibus subquadratis et usque ad 64  $\mu$  crassis, inferioribus diametro 1–2-plo longioribus et usque ad 80  $\mu$  crassis, apice subulatis, inferne pinnatis, superne inferiore latere pectinatis; pinnulis simplicibus vel raro semel divis, inferne

20–52  $\mu$  crassis, cellulis diametro 1–1.5-plo longioribus, apice subulatis; cellulis glandulinis numerosis, 22–40  $\mu \times$  15–32  $\mu$ , in pinnulis brevioribus singulatim supra cellulas tres sitis; chromatophoris numerosis, disciformibus. Fructus ignoti.

Frond ca. 5 mm. high, sparsely branched and oppositely pinnate, creeping on the branches of other algae, such as *Ceramium* sp. and *Gelidium subcostatum*, by means of crested rhizoidal filaments arising from the basal cells of pinnae; branches produced from the basal cells of pinnae, up to 120–150  $\mu$  diam., with lower cells 1.5–3.5 and upper cells 0.5–2 diam. long, and apical cells 8  $\mu$  diam.; pinnae lanceolate, slightly constricted at septa, the basal cells being subquadrate and up to 64  $\mu$  diam., lower cells being 1–2 diam. long and up to 80  $\mu$  diam., subulate at apices, pinnate below, pectinate on the lower side in the upper portion; pinnulae simple or rarely once divided, 20–52  $\mu$  diam. below, with cells 1–1.5 diam. long, subulate at apices; gland cells abundant, 22–40  $\mu \times$  15–32  $\mu$ , sitting singly over three cells on short pinnulae; chromatophores numerous discs. Reproductive organs unknown.

*Japanese name:* FUSANE-KASANEKUSA (nom. nov.).

*Type:* Epiphytic on other algae, e.g., *Gelidium subcostatum* Okamura and *Ceramium* sp., Shirahama, Prov. Bōshū. T. Inaba 350, Mar. 11, 1944 (Herbarium, Dept. Fish., Hokkaido Univ.).

This species of *Antithamnion* is one of those bearing gland cells of the scaphoid type, or those resting laterally on two or three cells. The frond is repent on the thallus of other algae, such as *Gelidium subcostatum* and *Ceramium* sp., and is attached by means of short crested rhizoidal filaments arising from the lowermost cells of pinnae. The pinnae and pinnulae are lanceolate, being sharply acute at the apex, somewhat thickened in the middle portion, and slightly attenuated toward the base. The pinnulae are

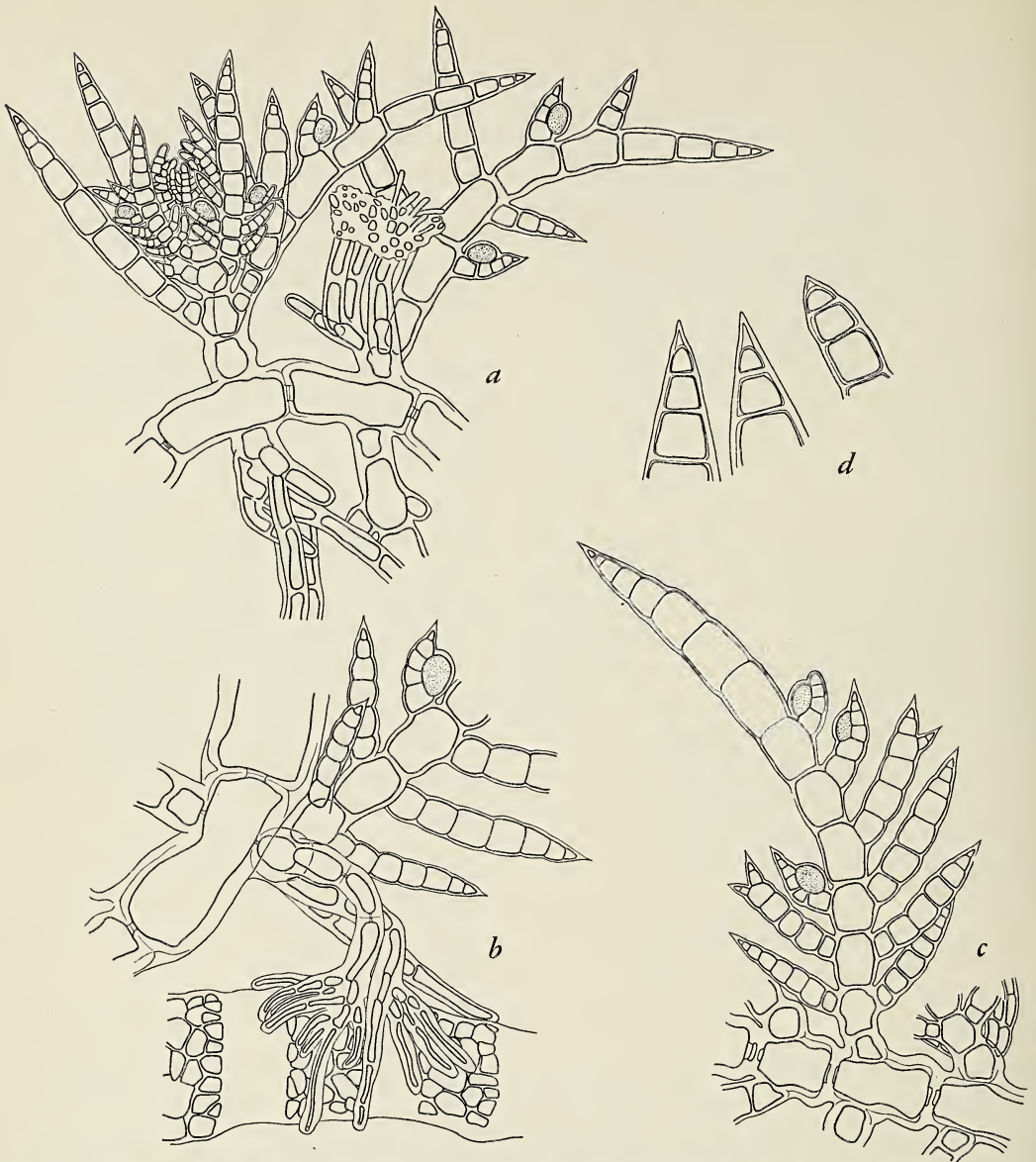


FIG. 3. *Antithamnion cristirhizophorum* Tokida and Inaba, sp. nov.: *a*, part of the lower portion of a frond, showing rhizoidal filaments, gland cells, and a young branch; *b*, the same, showing a tuft of rhizoidal filaments attached to a branch of *Ceramium* sp.; *c*, a pinna bearing nine pinnulae, two of which are once-divided pseudo-dichotomously near the tip; *d*, the tips of three ultimate ramuli. *a* and *c*,  $\times 137$ ; *b*,  $\times 150$ ; *d*,  $\times 480$ .

usually simple, but rarely pseudo-dichotomously divided at their apices.

*Platythamnion horridum* Tokida and Inaba,  
sp. nov.

Figs. 5*a, b*; 6*a-d*; 7*a-d*

Fronde usque ad 2 cm. alta, subdichotome

repetite ramosa, pinnis quaternis dense verticillata; pinnis lateralibus maturis brevissimis, 80–200  $\mu$  longis, ad basin 22–46  $\mu$  crassis, axibus 5–7-cellularibus, oblanceolatis, superiore latere pectinatis, in inferiore parte binis seriebus pinnularum ramosorum ornatis, cellulis basalibus inferiore latere nonnum-



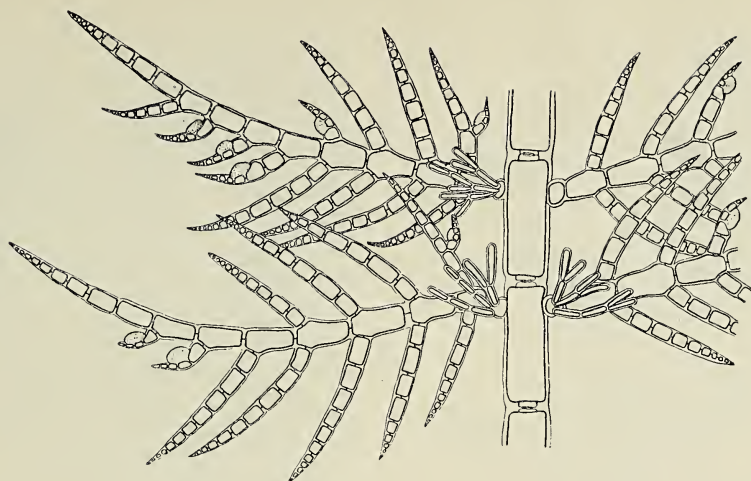


FIG. 4. *Antithamnion cristirbizophorum* Tokida and Inaba, sp. nov. Middle portion of a main branch showing pinnae, pinnulae, gland cells, and rhizoidal filaments.  $\times 100$ .

quam etiam pinnula singula simplici vel ramoso ornatis; pinnis transversalibus laterilibus minoribus, irregulariter ramosis; pinnulis ultimis subulatis, cellulis apicalibus ca.  $5\ \mu$  crassis; ramis principalibus usque ad  $120\text{--}160\ \mu$  crassis, cellulis diametro 1–3-plo longioribus, cellulis apicalibus  $14\ \mu$  altis,  $10\text{--}12\ \mu$  crassis, cellulis basalibus superiore (interiore) latere plerumque nulla pinna laterali ornatis; cellulis glandulinis numerosis, supra unam cellulam lateraliter sitis, usque ad  $34\ \mu \times 30\ \mu$ ; chromatophoris numerosis, taeniatis; rhizoidibus a cellulis basalibus pinnarum inferiorum emittentibus,  $10\text{--}30\ \mu$  crassis; tetrasporangiis in pinnis sessilibus,  $36\ \mu \times 34\ \mu$ , cruciatim divisis; spermatangiis et ramulis carpogonatis ignotis.

Frond up to 2 cm. high, repeatedly subdichotomously branched, with whorls of four pinnae; the two lateral pinnae in mature stages very short,  $80\text{--}200\ \mu$  long,  $22\text{--}46\ \mu$  diam. at the base, with 5–7-celled axis, which is oblanceolate, pectinate on the upper side, with two rows of branched pinnulae in the lower portion, sometimes with also a single pinnula, simple or branched, on the lower side of the basal cell; the two transverse pinnae smaller than the lateral ones, irregularly

branched; ultimate pinnulae subulate, ca.  $5\ \mu$  diam. at the apex; main branches up to  $120\text{--}160\ \mu$  diam., with cells 1–3 times as long as broad, apical cells  $14\ \mu$  long,  $10\text{--}12\ \mu$  diam., basal cells usually with no lateral pinna on the upper (inner) side; gland cells numerous, sitting laterally on one cell, up to  $34\ \mu \times 30\ \mu$ ; chromatophores numerous narrow bands; rhizoids produced from the basal cells of lower pinnae,  $10\text{--}30\ \mu$  diam.; tetrasporangia sessile on pinnae,  $36\ \mu \times 34\ \mu$ , cruciately divided; sexual organs unknown.

*Japanese name:* ONI-NO-YOTSUBAGUSA (nom. nov.).

*Type:* Growing on the shells of *Ostrea*, collected off the shore near the Fisheries School, Tateyama, Prov. Bōshū. *T. Inaba* 403, Apr. 18, 1944 (Herbarium, Dept. Fish., Hokkaido Univ.).

One of the leading characters of this new species is that the larger (pinnae laterales) of the two pairs of pinnae is comparatively short, usually 1–1.5 times, but rather rarely more than two times, as long as the diameter of the cells of the main axis. Since both the lateral and transverse pinnae are short and adorned with ultimate ramuli, which are sharply acute at their apices as in other

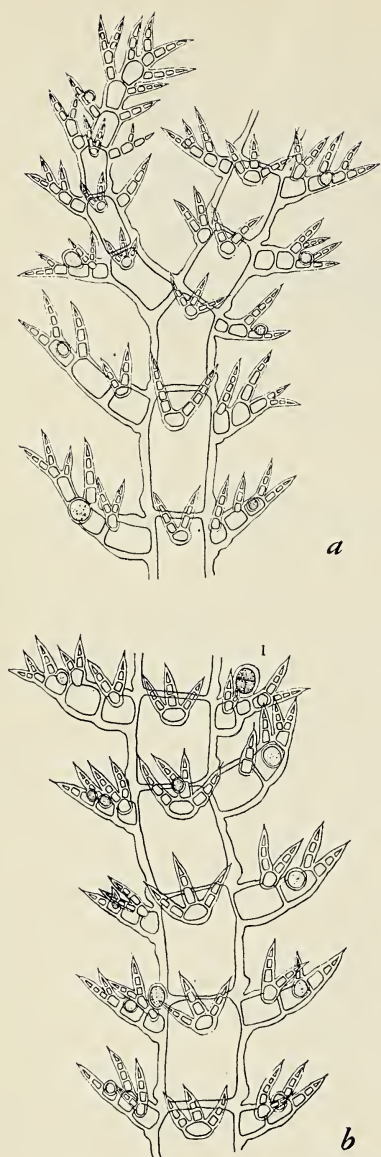


FIG. 5. *Platythamnion horridum* Tokida and Inaba, sp. nov.: *a*, middle portion of a frond, showing the mode of branching, pinnae laterales, pinnae transversales, and gland cells; *b*, the same, showing a tetrasporangium (1). *a* and *b*,  $\times 150$ .

known species of the genus, the main axis looks as if it bore verticillate spines on each segment, and the frond presents as a whole a quite spiny appearance. The specific name as well as the Japanese name is given with reference to this appearance. The frond is

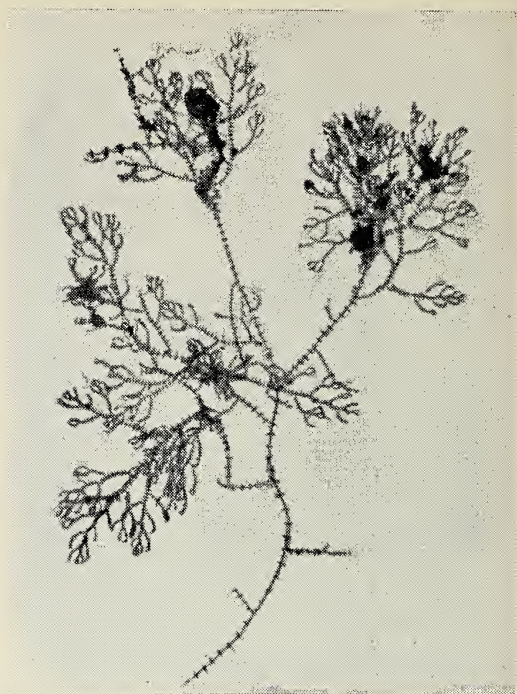


FIG. 6. *Platythamnion horridum* Tokida and Inaba, sp. nov. Type specimen.  $\times 4$ .

subdichotomously branched, and the branches often lack an adaxial lateral pinna on their lowermost cell. In these respects our species does not differ from other known species of *Platythamnion* (cf. Kylin, 1925: Fig. 34*a*; Tokida, 1942: Fig. 8*b*).

### *Acrothamnion pulchellum*<sup>3</sup> J. Agardh

Figs. 8; 9*a-e*; 10*a-f*; 11

J. Agardh, *Analecta Algologica*, p. 25, pl. 1, figs. 6–10, 1892; De Toni, *Sylloge Algarum*, 6: 451, 1924 (*nomen*). (*non Acrothamnion pulchellum* as interpreted by Yendo [Notes on Algae new to Japan, V. In: Bot. Mag. Tokyo 30 (355): 262, 1916] and by Yamada [Marine Algae of Mutsu Bay, II.

<sup>3</sup>In accordance with Article 61 of the International Rules of Botanical Nomenclature the specific epithet *pulchellum* is not available for transfer, since *C. pulchellum* Harvey (1855) was invalidated by *C. pulchellum* C. Agardh (1828).





FIG. 7. *Platythamnion horridum* Tokida and Inaba, sp. nov.: *a*, apical portion of a frond, showing the growing apex; *b*, part of lower portion of a frond, showing the base of a branch, the lowest cell of which lacks the adaxial pinna (1); *c*, three pinnae laterales, showing pinnulae; *d*, tips of two ultimate ramuli. *a*,  $\times 245$ ; *b* and *c*,  $\times 150$ ; *d*,  $\times 480$ .

In: Sci. Rep. Tohoku Imp. Univ., 4th Ser. Biol., 3(4): 528, Fig. 22, 1928]).

*Syn. Callithamnion pulchellum* Harvey. Some account of the marine botany of the colony of Western Australia. Trans. Royal Irish Academy, 22: 561, 1855; Phycologia Australis 5: Synoptic Catal., p. liv. no. 692, 1863; J. Agardh, Sp. Alg., 3(1): 20, 1876; De Toni, *loc. cit.*, 4(3): 1338, 1903; A. H. S. Lucas & Florence Perrin, The seaweeds of South Australia, II. The red seaweeds, p. 333, 1947. (*non Callithamnion pulchellum* C. Agardh, Sp. Alg., 2: 175, 1828).

Frond 5–10 mm. long, epiphytic on the thallus of *Gelidium subcostatum*, sparsely branched, partly repent, attached to the sub-

stratum by means of rhizoids arising from the basal cell of the lower, and sometimes also upper, pinnae; lateral branches arising from the basal cell of the pinnae, axial cells of the branches 37–60  $\mu$  diam. and 1.2–3 times as long as broad below, 60–86  $\mu$  diam. and 2.5–3.5 times as long as broad above, and 1–2 times as long as broad in the subapical portions, often provided with three pinnae; lateral pinnae opposite, 120–345  $\mu$  long, with opposite pinnulae on each segment except the basal; pinnulae simple or rarely once divided, attenuate but not acute toward the apices, composed of subquadrate cells slightly constricted at their septa, 10–20  $\mu$  diam. at the base, 5–10  $\mu$  diam. at the apical cells;



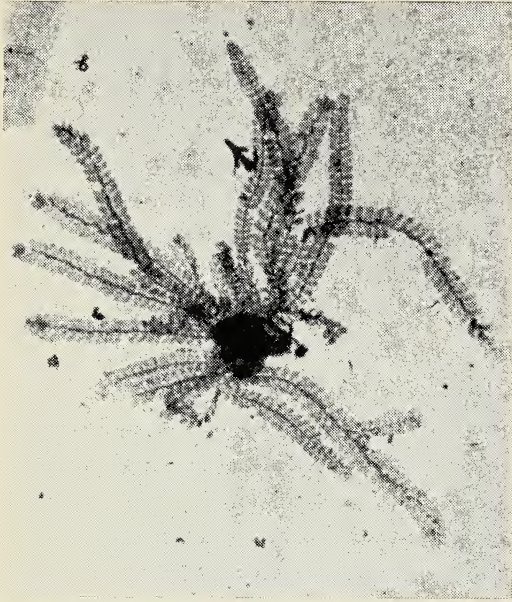


FIG. 8. *Acrothamnion pulchellum* J. Ag. Specimen from Shirahama.  $\times 6$ .

axes of pinnae 25–30  $\mu$  diam. at the basal, 35  $\mu$  diam. at the suprabasal, and 20  $\mu$  diam. at the subapical cells; transverse pinnae secund, smaller than the lateral ones, 72–280  $\mu$  long, 10–20  $\mu$  diam., simple or sparsely pinnulate above, in the latter case provided with opposite pinnulae on the apical segment and sometimes also with opposite or secund pinnulae on the subapical segments; gland cells always on the apices of pinnae and pinnulae, sitting between the two apical pinnulae on two basal cells of either of them, 10–20  $\mu$  high, 20–25 (–30)  $\mu$  diam.; chromatophores discoid, numerous. Sexual reproductive organs unknown; tetrasporangia observed on a specimen from Western Australia.

*Japanese name:* KUJAKU-HANEMO (nom. nov.).

*Specimen:* Growing on the thallus of *Gelidium subcostatum* Shirahama, Prov. Bōshū T. Inaba 351, Mar. 11, 1944 (Herbarium, Dept. Fish., Hokkaido Univ.).

This beautiful species was discovered to be partly repent upon the thallus of *Gelidium subcostatum*, being attached by means of

many rhizoidal filaments issuing from the lowermost cell of the pinnae at the lower portion of the frond and not uncommonly near the apical portion as well. The plant stands close to *Antithamnion* in the characters of the growing point and in the method of branching as well as in the possession of opposite pinnae on each segment of the main axis; but on the other hand it differs from that genus in having a single dwarf accessory pinna or transverse pinna on each axial segment of branches in addition to the above-mentioned opposite pinnae, and in having quite characteristic apical gland cells. The branches arise from the lowermost cell of either or both of the opposite principal pinnae. The axial segment of branches gives rise near the top to three pinnae in all, or two opposite larger pinnae and a single smaller pinna, of which the latter arises in the direction crossing at right angles with the plane including the two opposite pinnae. The smaller transverse pinnae are secund on one side of the main axis which corresponds to the side from which branches and rhizoidal filaments arise or to the underside of the repent portion of the frond. The principal pinnae bear two opposite pinnulae, as a rule, on each axial cell except the lowermost one. The number of the opposite pairs of the pinnulae for one principal pinna ranges from 5 to 11 (as indicated by our counts of many pinnae, amounting to 224 in all). The frequency of each number was as follows:

Number of pairs:	5	6	7	8	9	10	11
Frequency:	1	5	11	47	98	59	3

As can be seen in the listing above, the pinnae with nine pairs of pinnulae were most frequent in occurrence. The spread of two opposite pinnulae and that of two opposite pinnae measures 90–225  $\mu$  and 240–690  $\mu$  in width, respectively. The accessory pinnae or transverse pinnae, in the typical form, bear at least one pair of opposite pinnulae on the apical axial cell, which is crowned



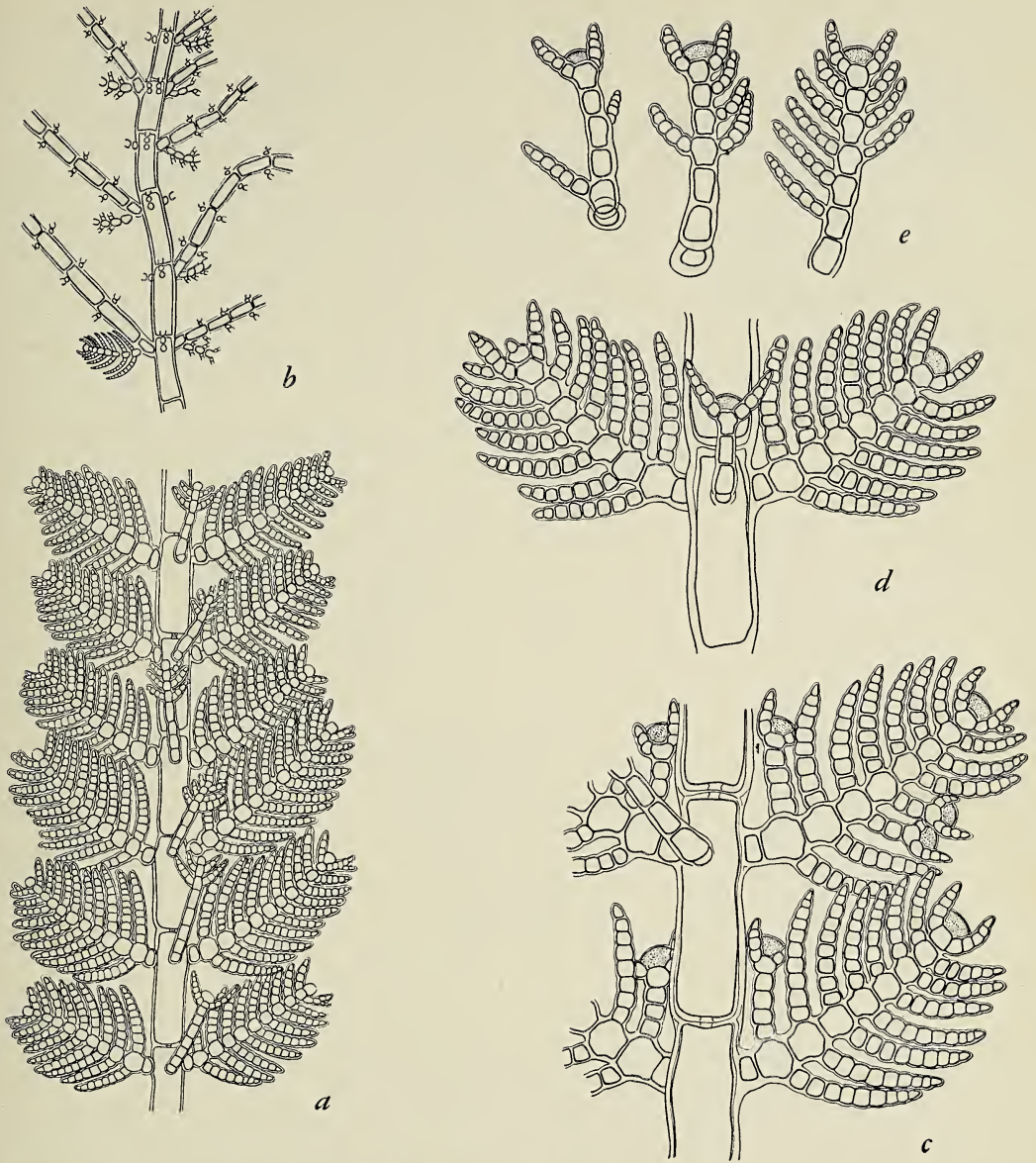


FIG. 9. *Acrothamnion pulchellum* J. Ag.: *a*, middle portion of a main branch, showing opposite pinnae laterales and second pinnae transversales; *b*, lower portion of a frond, showing the mode of branching, details of all the pinnae but one having been omitted; *c*, six pinnulae crowned with apical gland cells; *d*, typical forms of both pinna lateralis and pinna transversalis, on the left side an exceptional pinna lacking the apical gland cell; *e*, three pinnae transversales, showing the variety of the arrangement of pinnulae. *a*,  $\times 75$ ; *b*,  $\times 40$ ; *c*, *d*, and *e*,  $\times 150$ .

with a gland cell. The occurrence of pinnulae on the rest of the cells of the axes is irregular. Although the accessory pinnae are as a rule single on each axial cell of branches, sometimes they happen to be absent on cer-

tain axial cells or two may be formed from each axial cell. In the latter case, two accessory pinnae stand side by side on the same side of the frond axis. The pinnulae, either on the principal or accessory pinnae, are gen-

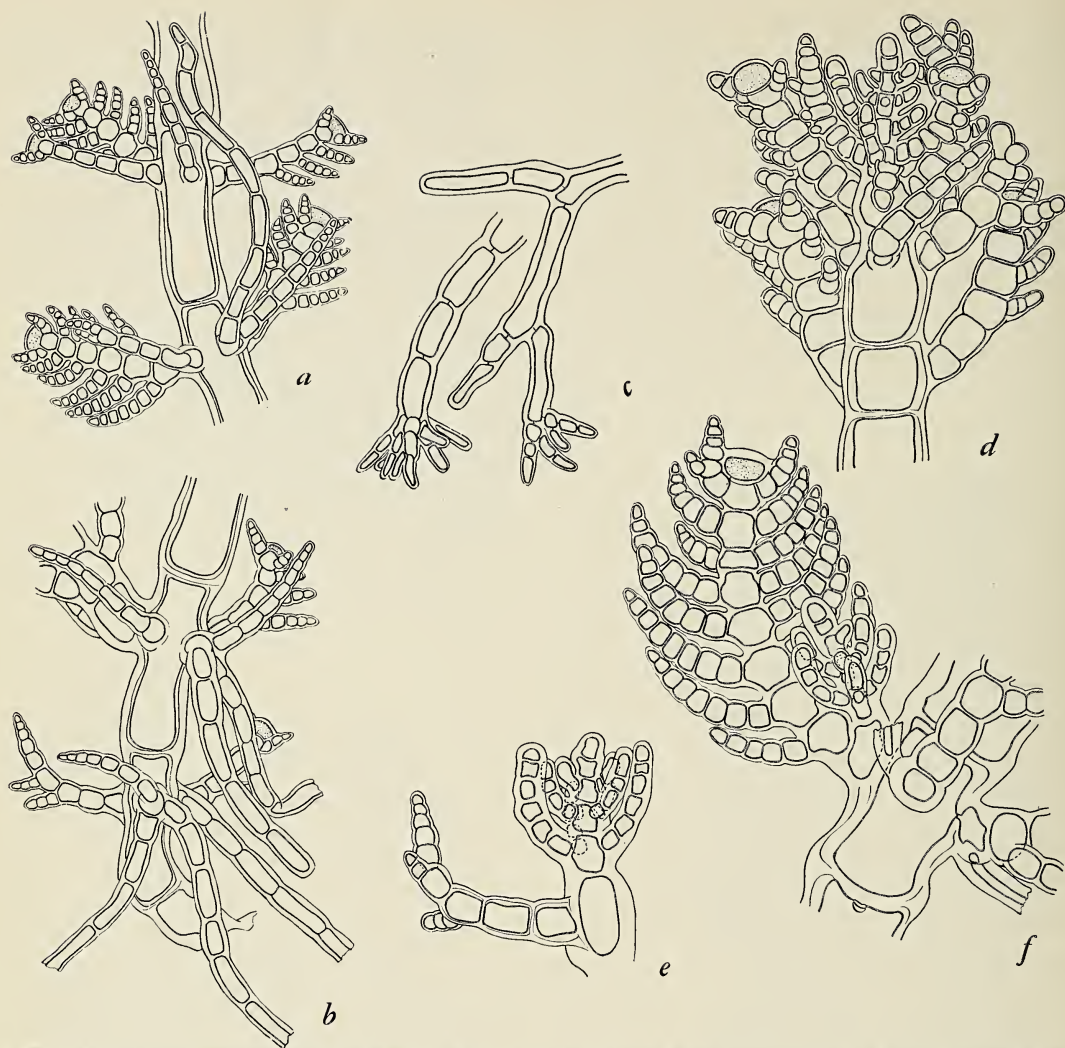


FIG. 10. *Acrothamnion pulchellum* J. Ag.: *a*, part of the lower portion of a frond, showing two pairs of pinnae transversales developing on the same side of the axis, and a rhizoidal filament arising from the lowest cell of a pinna; *b*, the same, showing rhizoidal filaments; *c*, the branching at the distal end of two rhizoidal filaments; *d*, apical portion of a short branch; *e*, very young branch developing from the lowest cell of a principal pinna; *f*, initial of a branch developing from the lowest cell of an upper principal pinna. *a* and *b*,  $\times 150$ ; *c*, *d*, *e*, and *f*,  $\times 245$ .

erally simple, with tapering but not acute tips. Rarely some of them on a principal pinna are crowned with two opposite ramuli supporting an apical gland cell at their fork, in just the same manner as in the apex of a pinna. In the lower portion of the frond, the structure of pinnae is apt to become irregular; in other words, pinnulae often disappear partly or entirely from principal

pinnae or accessory pinnae, respectively. An accessory pinna which thus remains entirely simple is no longer crowned with a gland cell. The gland cell rests solitarily at the apex of each pinna, always on five cells covering the uppermost axial cell of the pinna and two lowermost cells of each pinnula arising oppositely from the uppermost axial cell of the pinna. The principal pinnae or lateral



pinnae present a feathery appearance which reminds one of the beautiful plumes from the gorgeously eyed train of the peacock, inasmuch as they bear distichous opposite pinnae on each axial cell (except for the basal one) and one large gland cell glittering at their apices. The Japanese name proposed for this species is based on that appearance. The reproductive organs unfortunately have not been discovered in our specimens. The description of the species given here is based upon our sterile specimens collected at Shirahama.

The writers owe the present identification to the suggestion of Prof. Y. Yamada, of the Faculty of Science in Hokkaido University, who once made a comparison of the Japanese specimens (which were then provisionally referred to *Acrothamnion pulchellum*) with Harvey's Austr. Alg., No. 539 (*Callithamnion pulchellum* Harv.), or the type specimen of *Acrothamnion pulchellum*, in Harvey's herbarium at Dublin, Agardh's herbarium at Lund, etc. (cf. Yamada and Inagaki, 1935: 37). He informed us that the authentic specimens of the species when seen under the microscope attracted his special attention by their possession of the quite characteristic apical gland cells. On the other hand, it is curious that we find no description of that organ in the diagnoses of the genus and the species given by Harvey, J. Agardh, De Toni, and Lucas & Perrin, if "*favellus*," which was described by Harvey as "*favellis simplicibus rachidem plumulae terminalibus*," is really comparable with the cystocarp and not with the gland cells as illustrated by J. Agardh (1892: Fig. 10) in a simple and equivocal figure. This figure seems to have nothing to do with the cystocarp but reminds us of an inflated axial cell of a pinna infected by a parasitic fungus (cf. Tokida, 1932: Fig. 5*b*). "*Pinnula . . . adparenter truncata*," illustrated in the same work of J. Agardh (Fig. 9), resembles quite well a simple accessory pinna lacking an apical gland cell in our

Japanese plant. "*Pinnulae steriles* (ad \*)," illustrated in Figures 6, 7, and 8, resemble abnormal lower pinnae lacking gland cells in our plant (cf. Figs. 10*b* and 10*e* in the present paper). The arrangement of the pinnae in our plant, which is distichous with two opposite compound pinnae spreading on the same plane, or, more frequently, tristichous with a more simply constructed pinna in addition to the opposite ones just mentioned, seems to agree with the description of the pinnae of *Callithamnion pulchellum* given by J. Agardh (1876), which runs as follows: "*pinnis geminis conformibus distichis oppositis pinnulatis, aut ternis una dispari simpliciore*." As to the validity of the tetrasporangium-bearing simple and subfiliform accessory pinnula, which was described and illustrated by J. Agardh (1892: Figs. 6, 7, and 8), as a character of generic importance, we are inclined to harbour a strong doubt since we could observe sessile tetrasporangia on a fragment of Harvey's original specimen of *Callithamnion pulchellum* (Alg. Austr. Exsicc., No. 539D) through the most generous kindness of Mme. Valerie May of the Division of Fisheries, Marine Biological Laboratory, Cronulla, New South Wales, Australia. In April, 1948, the senior author received a letter from her answering his request to compare some figures of the Japanese plant drawn by himself with the authentic specimens of *Acrothamnion pulchellum* J. Ag. Mme. May kindly enclosed in her letter a fragment of Harvey's specimen deposited in the National Herbarium of New South Wales, Sydney. In examining the fragment under the microscope, it was quite satisfactorily ascertained that our Japanese plant coincides with Harvey's species in every morphological characteristic. As the fragment fortunately bears tetrasporangia, the authors wish to give here a thorough description and illustrations of them.

The tetrasporangia-bearing branch is marked by having frequently a couple of

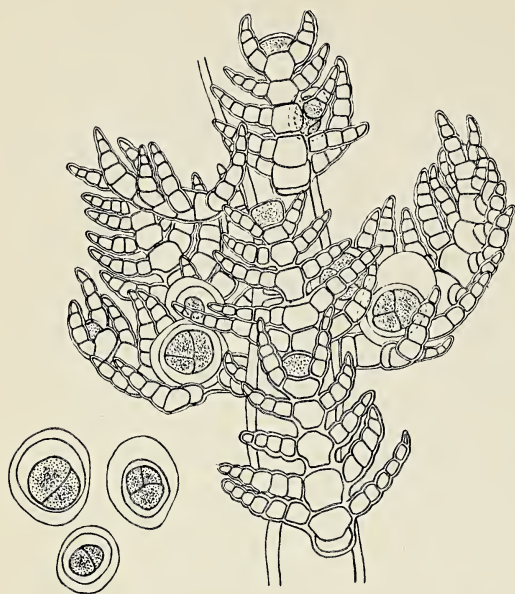


FIG. 11. *Acrothamnion pulchellum* J. Ag. Part of a tetrasporiferous fragment of Harvey's specimen (Alg. Austr. Exsicc. No. 539D) collected at Port Fairy, Victoria, in 1855, showing the sessile tetrasporangia with inflated membranes, developing on the upper side of the lower portion of the pinnae. Three sporangia in various stages of development are shown separately.  $\times 245$ .

compound accessory pinnae on the ventral side of each of its segments. The sporangia mounted in glycerine-water measure  $32\text{--}48\ \mu$  long and  $24\text{--}44\ \mu$  wide, excluding membranes. Including the outer layer of the membrane, which is usually swollen to a remarkable extent, a sporangium is  $86\ \mu$  long and  $72\ \mu$  wide and contains a spore mass measuring  $38\ \mu$  long and  $36\ \mu$  wide. The same sporangium is  $52\ \mu$  long and  $48\ \mu$  wide, including the inner layer of the membrane. A young immature sporangium in which the contents are undivided and measure  $20\ \mu$  by  $18\ \mu$  is  $38\ \mu$  long and  $34\ \mu$  wide, including the inner layer of the membrane, and  $60\ \mu$  long and  $52\ \mu$  wide if the outer layer is included. The sporangia are sessile, standing on the adaxial (upper) side of the basal segment of, usually, the lowermost pinnule of the principal and accessory pinnae. They divide cruciately by two successive divisions, first by a transverse

wall and second by two walls perpendicular to the first as well as to each other. The opposite principal pinnae are slightly bent upward and toward the dorsal side of the axis, so as to form, along with the accessory pinnae, a fence around the axis in order to protect the tetrasporangia (cf. Fig. 11).

### *Pleonosporium Tobyamanum*

Tokida and Inaba, sp. nov.

Figs. 12a, b; 13a, b; 14a, b; 15a-c

Fronde  $1\text{--}1.5$  cm. alta, rhizoidibus longis et simplicibus vel ramosis, a cellulis basalibus pinnarum inferiorum deorsum vel a cellulis inferioribus axium principalium lateraliter emittentibus adfixa; axibus principalibus inferne usque ad  $300\text{--}315\ \mu$  crassis, ad basin in axes nonnullis divisis, ecorticatis, cellulis diametro  $1.5\text{--}3$ -plo longioribus, ad septa leve inflatis; ramis et pinnis alternis et distichis; cellula basali rami quadrata, pinna nulla, cellula insequenti superiore latere pinna una praedita; pinnis simplicibus vel ramosis, lineari-lanceolatis, leviter incurvis, apica obtusis, cellulis apicalibus  $22\text{--}24\ \mu$  crassis, cellulis basalibus pinnarum inferiorum in ramis inferioribus inferiore latere pinnulis simplicibus vel ramosis; chromatophoris numerosis, brevibus et taeniatis; sporangiis in pinnis et pinnulis sessilibus, plerumque in latere superiore secundis, sed raro etiam in latere inferiore sparsis, ellipsoideis,  $70\text{--}106\ \mu$  longis et  $50\text{--}78\ \mu$  latis, sporis pluribus ornatis; antheridiis in latere superiore ramulorum ultimorum secundatis; procarpiis subterminalibus; cystocarpiis terminalibus, ramulis involucrantibus nullis; cellula glandulina nulla.

Fronde  $1\text{--}1.5$  cm. high, attached to the substratum by means of simple or branched rhizoidal filaments, being produced downwardly from the basal cell of the lower branches or laterally from the lower segments of the main axes; main axes up to  $300\text{--}315\ \mu$  diam. below, divided into several main axes near the base, uncorticated, with cells  $1.5\text{--}3$  times



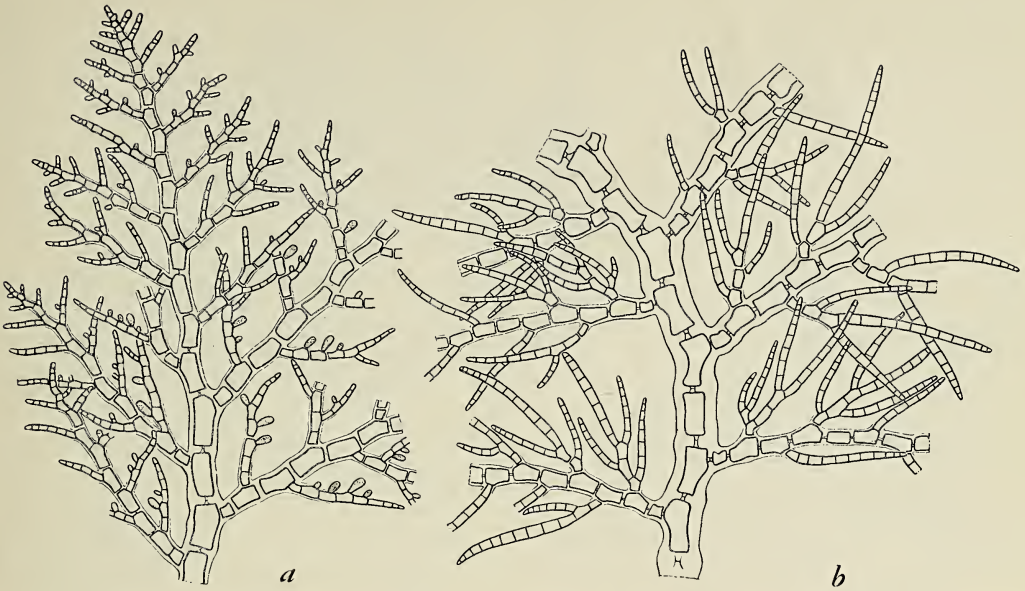


FIG. 12. *Pleonosporium Tobyamanum* Tokida and Inaba, sp. nov.: *a*, apical portion of a main axis; *b*, lower portion of a main axis, showing branching of the side branchlets on the lower segments of the branches. *a* and *b*,  $\times 33$ .

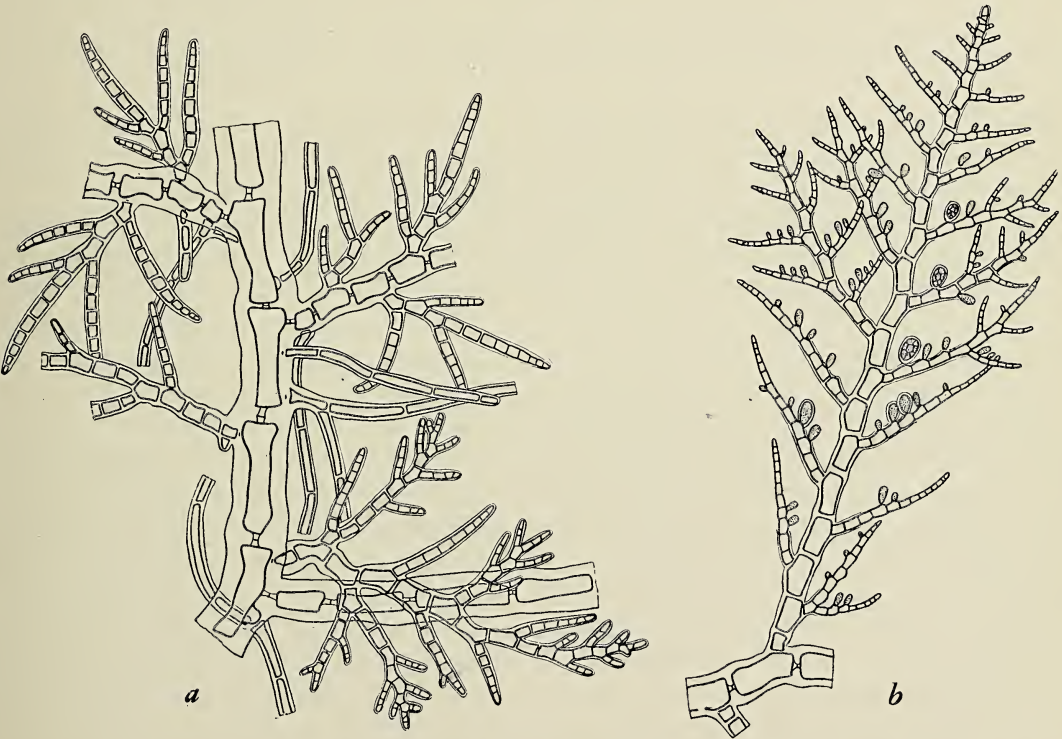


FIG. 13. *Pleonosporium Tobyamanum* Tokida and Inaba, sp. nov.: *a*, branch with sporangia; *b*, basal portion of a frond, showing rhizoids. *a*,  $\times 40$ ; *b*,  $\times 65$ .

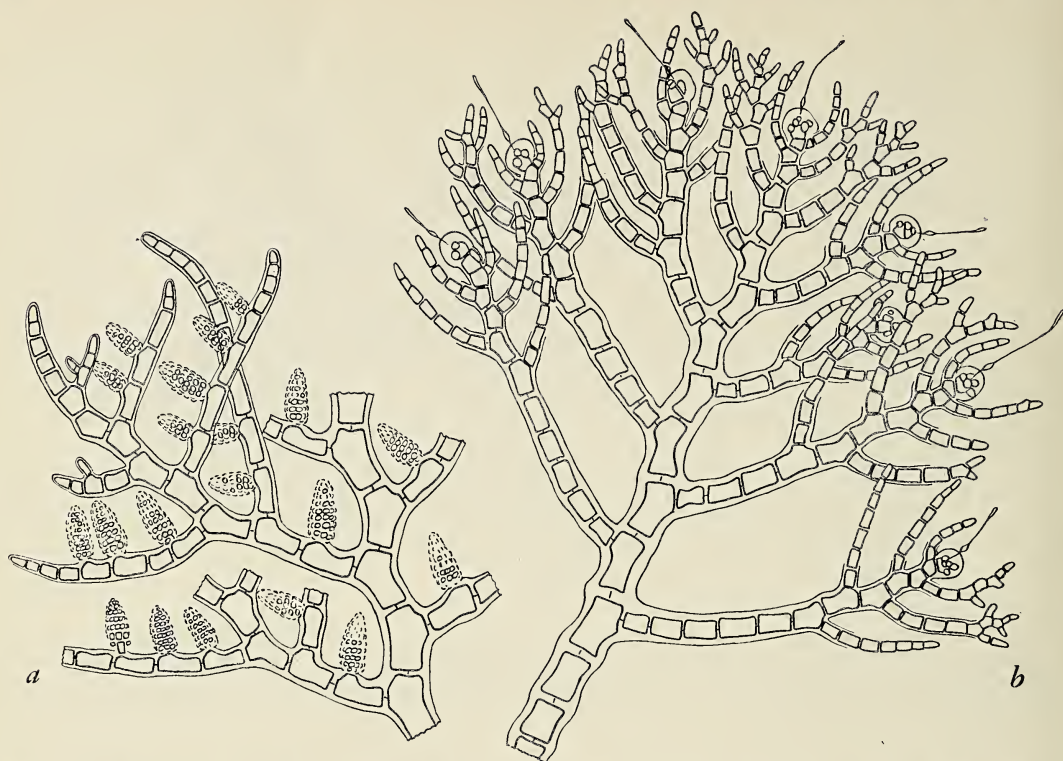


FIG. 14. *Pleonosporium Tobyamanum* Tokida and Inaba, sp. nov.: *a*, apical portion of a branch with procarps; *b*, branch with antheridia. *a*,  $\times 150$ ; *b*,  $\times 98$ .

as long as broad, slightly inflated at joints; branches and pinnae alternate and distichous; the lowermost cell of branches quadrate, with no pinna, the next cell with a pinna on the adaxial side; pinnae simple or divided, linear-lanceolate, slightly incurved, blunt at the apex,  $22-24\ \mu$  diam. at the apical cells, with a simple or divided pinnula on the abaxial side of the lowermost cell of a few lower pinnae in the lower branches; chromatophores numerous, short slender bands; sporangia sessile, usually secund on the adaxial side of pinnae and pinnulae but rarely also scattered on the abaxial side of pinnae, ellipsoidal,  $70-106\ \mu$  long and  $50-78\ \mu$  broad, with many spores; antheridia secundate on the upper side of the ultimate ramuli; procarps subterminal; cystocarps terminal, with no involucre; gland cell absent.

*Japanese name:* TOHYAMA-KUSUDAMA (nom. nov.).

*Type:* Growing on rocks, Mera, Prov. Bōshū. *T. Inaba* 402, Apr. 10, 1944 (Herbarium, Dept. Fish., Hokkaido Univ.).

In 1917, Yendo (1917: 91) referred a plant of *Pleonosporium* from Cape Inubō to *P. venustissimum* (Kütz.) De Toni, no doubt following the specific conception entertained by De Toni (1903), who had amalgamated *P. vancouverianum* J. Ag. with this species. Kylin (1925: 57) has disagreed with De Toni's view, stating that: "Kützing's figure (Tab. Phyc., 12: pl. 1) shows that in *C. venustissimum*<sup>4</sup> the side branch from the undermost cell of a branch often occurs on the upper side, but in *Pl. vancouverianum* it always occurs on the lower side." If that be the case, there arises a question as to the nature of the side branch under consideration in Yendo's plant.

<sup>4</sup>As a species of *Callithamnion*.



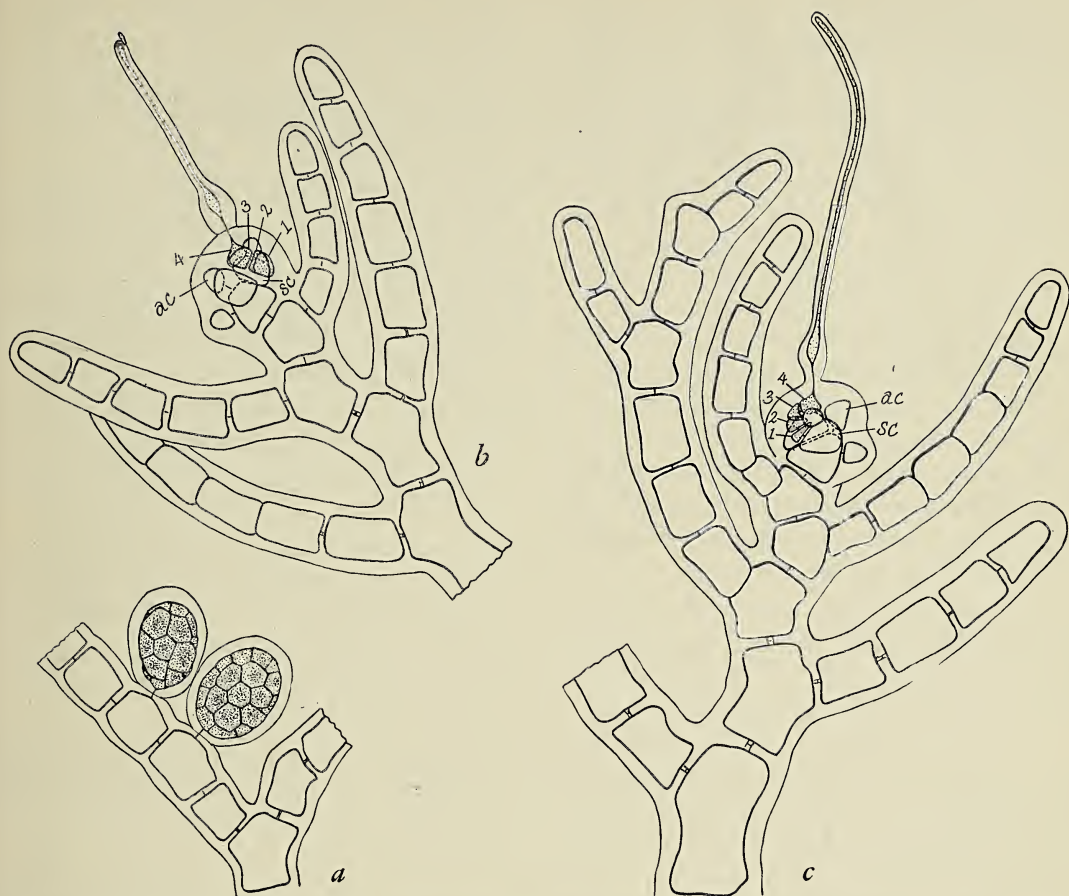


FIG. 15. *Pleonosporium Tobyamanum* Tokida and Inaba, sp. nov.: *a*, two sporangia; *b* and *c*, apical portions of fertile pinnae, showing carpogonial branches: 1, 2, 3, and 4, carpogonial branch cells; *sc*, supporting cell or fertile pericentral cell, provided with a carpogonial branch and a sterile cell; *ac*, apical cell of the pinna. *a*,  $\times 150$ ; *b* and *c*,  $\times 344$ .

In the spring of 1944, the junior author collected a *Pleonosporium* at Mera, Bōshū province, not far distant from Cape Inubō. In general characters it resembles the two species mentioned above, but is not identical with either of them, differing in certain respects, especially in the entire absence of the side branch or pinna on the lowermost cell of a branch. The side branch on the cell next to the lowermost one arises always on the adaxial side of the branch. In this respect our plant shows a resemblance to *P. vanconverianum* rather than to *P. venustissimum*. According to the brief description by Yendo,

the main branches of his plant seem to have somewhat longer cells than those of ours. As to the rhizoidal filaments. Yendo describes merely those growing downward from the basal cell of the pinnae, while our plant has in addition lateral rhizoidal filaments which issue from the lower segments of the main axis and which rarely become as thick as the main axis (Fig. 13*b*). It is quite probable that our plant is identical with Yendo's, but at present we cannot settle the question as we have had no chance to examine Yendo's original specimen. In any event, we believe the plant in question is new to science, and

we propose here to name it *Pleonosporium Tohyamanum* in honour of Mr. Nobuo Tohyama, director of the Fishery Experiment Station of Chiba prefecture, through whose kindness the authors have obtained many facilities for carrying out their phycological studies.

#### SUMMARY

1. In this paper is reported the discovery of four species of red seaweeds which are considered to be new to science and which belong to the genus *Antithamnion* and its allied genera in the family Ceramiaceae. The occurrence of an Australian species of the same group from the coast of Bōsō Peninsula near Tokyo Bay is also reported.

2. New species here described are as follows: *Antithamnion basisporum*, *Antithamnion cristirbizophorum*, *Platythamnion horridum*, and *Pleonosporium Tohyamanum*.

3. The occurrence in the northwestern part of the Pacific Ocean of *Acrothamnion pulchellum* J. Ag., which was originally reported from the west and south coasts of Australia in 1855, is established by comparing Japanese specimens with a fragment of Harvey's original specimen collected at Port Fairy, Victoria.

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## *Harpodon nehereus*, a Non-luminous Fish

YATA HANEDA<sup>1</sup>

THE GENUS *Harpodon* of the fish family Synodontidae is found in the seas of India, Burma, Malaya, Sumatra, Java, Borneo, Thailand, Indo-China, and China. It has been recorded from Zanzibar and East Africa; a single species has been recorded from Japan.

Four species appear to be known: *Harpodon nehereus*, *H. squamosus*, *H. macrochir*, and *H. mortenseni*.

The first, *H. nehereus* (Ham. Buch.), is the commonest and occurs in varying abundance in shallow coastal waters and estuaries, mostly in India, Burma, Malaya, Java, Sumatra, and Borneo. When salted and dried it forms the well-known product known as Bombay duck, or bummaloe, which serves as a condiment with curries. In Malaya, Java, and Sumatra it is generally known either alive or dead as ikan lumi or luli or aruan tassik, although occasionally it may have other names in scattered localities. As far as is known, *H. nehereus* is the only species found in Malaya (Günther, 1864; Fowler, 1938).

The first scientific reference to the fish known as "Bombay Duck" is found in Hamilton's book on Gangetic fishes (Hamilton-Buchanan, 1822). The species was discovered by him in the mouths of the Ganges, and was doubtfully referred to the genus *Osmerus*. However, in 1825 Lesueur proposed the genus *Harpodon* for Hamilton's species of *Osmerus*. The synonyms of *H. nehereus* are numerous. It was first known as *Osmerus* ? *nehereus* (Hamilton, 1822) then later as *Salmo* (*Harpodon*) *microps* (Lesueur, 1825), *Saurus* *Ophiodon* (Cuvier et Valenciennes,

1849), *Saurus nehereus* (Cantor, 1850), and finally as *Harpodon nehereus*.

The second species, *H. squamosus*, was taken in deep water in the Bay of Bengal, at depths varying from 120 to 300 fm., and was described by Alcock in 1891.

The third species, *H. macrochir*, was named by Günther (1887: 180) from a single specimen from Tokyo, Japan. Neither the depth nor the locality in which it was caught is known.

The fourth species, *H. mortenseni* (Hardenberg, 1933), was caught by trawl at a depth of 300 m. by Dr. Mortensen, after whom the species was named. It was taken in the Bali Sea.

There seems to be no reason why *H. squamosus* should not be admitted to the deep-sea fauna on the evidence available; however, there is no evidence to show that either *H. macrochir* or *H. nehereus* is a deep-sea fish.

Günther (1887) says the species *H. macrochir* is named from a single specimen 27 inches long which was obtained at Tokyo, Japan, although at what depth it was taken is not known, "but it is evident from its organization that it should be referred to the deep sea fauna."

Boulenger (1904) states that *Harpodon nehereus* is adapted to a bathybial existence, and at the same time comments on its luminosity, although stating that it is not known to inhabit deep water and is not confined to the sea but is abundant in estuaries. He points out further that *H. squamosus* lives in depths from 120 to 300 fm. but says nothing about its luminosity. Since so many statements have appeared in ichthyological publications concerning its luminosity, I decided

<sup>1</sup>Tokyo Jikeikai Medical College. Manuscript received January 28, 1949.

to ascertain the nature of the luminosity, and, if it was found to be luminous, to locate and describe the luminous organs.

Cuvier and Valenciennes (1849), discussing the economic uses of this fish, stated that they were informed "that when exposed to the air they give out during the night a living phosphorescent luminescence." Cantor (1850) said, "It is very short lived . . . and the whole body becomes at certain seasons brilliantly phosphorescent." Günther (1880: 584) stated "that when newly taken its body is brilliantly phosphorescent." Kemp (1917: 238), in his observations on specimens from the Matlah River, was not able to corroborate this statement. Hora (1934) also agrees with Kemp's observations. Boulenger (1922: 613) states that "*H. nehereus* when newly taken is brilliantly phosphorescent all over the body." Kyle (1926) wrote of "the remarkable *Harpodon* which when caught becomes brilliantly luminescent all over the body." Norman (1931) stated "it is brilliantly phosphorescent all over when newly caught without possessing any light producing organs."

Whether these statements are the results of personal observation is not known, but they seem to refer to the condition of the fish after it has been caught or "newly caught," whatever this may mean.

Cuvier's material was undoubtedly dead, as was Cantor's, since the latter comments on the fact that the fish is short lived. None of the other statements refers to actual living material, and the expression "newly caught," at least as far as Malayan material is concerned, may have no significance whatever for the following reasons.

The *Harpodon* which are caught in Malaya are taken in nets which are set in estuaries, or between adjacent islands where there is a strong tidal stream during the ebb and flood of the tides.

The nets are long bag-like affairs with meshes almost as fine as those of coarsely

woven sackcloth. They lie on the bottom and are furnished with a wide-open mouth which faces the current. Through this mouth is swept into the nets, by the tidal stream, a mixed assortment of feebly swimming fishes, squid, crustacea, jellyfish, and a miscellaneous assortment of debris from the land, such as leaves, twigs, etc. Once in the net there is no escape for those animals which cannot swim against the stream, and they remain crammed and compressed in the net by the constant addition of material which collects there.

The nets remain there without attention until slack water, when they are lifted, emptied, and reset to face the stream as it reverses its direction with the change of tide. Most of the fishes and other animals are dead or dying when the nets are lifted, and only those caught last may be alive, since they are not subjected to anything but the pressure of the water.

The time during which the nets remain unattended is about 6 hours, and most of the catch is taken during that 3-hour period when the tidal stream flows strongest, which may occur an hour to an hour and a half after the setting of the net and last until an hour to an hour and a half before lifting it. There is a further delay in the handling of the catch when the fishermen have to lift the nets, dump the catch into a boat (incidentally dumping the dead on top of the more recently caught, crushing and killing them in turn), and then row their catch ashore for sorting. This may account for a delay of at least an hour if not more, and it should be realised that by this time there is little chance of securing any living specimens of such a feeble, short-lived fish as *Harpodon*. "Newly caught" material may have been dead for 5 to 6 hours at the most and for 2 or 3 hours at the least, and this fact is very important. There is no definite record of any observation on the luminosity of actually living material. In order to secure live specimens I had to



stay by the nets, hoping that with careful sorting there might be some living material available when the nets were lifted.

Fortunately I was able to secure some, and the results will show the significance of distinguishing between living material and that which may have been the material described so often as "newly caught."

I examined very carefully a considerable amount of dead but fresh material in the Singapore Fish Market during November, 1943, and February, 1944, in order to determine whether there were any luminous organs or luminous spots, but failed to find any. In April, 1944, I was able to obtain living material by crossing over to Karimon and actually staying by the nets which are set in the Gelam Straits off Tanjong Balai, Karimon Island, Rhio Archipelago.

It is significant that of all the living specimens I obtained, not a single one displayed the slightest luminescence. On the other hand, all of the dead specimens were strongly luminescent. In some cases the whole body was luminous; in others only a part was luminous. Moreover, the luminosity in some cases was confined to the surface of the whole body, while in others it could be seen deep inside the body.

Another interesting observation was that the luminosity of *Harpodon* was much brighter than that of the other kinds of fish, crustaceans, etc., in the catch, which, incidentally, were luminous, but to a lesser degree.

Bacteriological cultures were made from both the outside and inside of the bodies of this dead luminous material, and subjected to the usual bacteriological tests. The results indicate that the luminosity of *Harpodon*, when dead, is due simply to luminous saprophytic bacteria and that it differs in no way from that which can be observed in other dead fish and other animals taken at the same time.

It must not be overlooked that the flesh of *Harpodon* is almost like jelly, possessing an

extremely high water content, and is an excellent medium for the easy invasion and rapid development of bacteria, much more so than the tough muscular flesh of other fishes and crustacea.

The rapidity with which bacteria develop in tropical countries is well known, and this case furnishes an excellent illustration. In 4 to 5 hours after death the effects of luminous bacteria are already visible on the surface of the body. After 7 to 8 hours luminosity can be seen to have extended to the innermost parts of the body.

It is clear, therefore, that what is meant by "newly caught" material should be expressed more precisely. More frequently this expression means "newly landed" either at the place normally used by fishermen for landing their catches, or perhaps in the market place, miles from where the fish were caught. The primitive and slow methods of handling and marketing fish in tropical countries are proverbial and there would be ample time for *Harpodon* to become luminous as a result of bacterial action even if "newly caught" according to tropical standards.

Luminosity is so associated with deep-sea fishes that it seems to be considered a reasonable possibility that if a fish is either luminous or an inhabitant of the deep sea it is probably both, especially if it has any resemblance to some well-known form of luminous deep-sea fish.

With its gaping mouth, large teeth, small eyes, and soft body, the resemblance of *Harpodon* to some of the Chauliodontidae might well encourage the belief that it was a deep-sea fish, and that the luminosity seen after death was normal during life. This resemblance to a deep-sea form misled even so great an authority as Günther (1880: 584).

*Acknowledgment:* I wish to express my hearty thanks to Mr. W. Birtwistle, former Director of the Fisheries Department of Singapore and Federated Malay States, who helped me in many ways during my stay in

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# The Noctuidae Catocalinae from New Caledonia and the New Hebrides (Lepidoptera)

PIERRE E. L. VIETTE<sup>1</sup>

THE LEPIDOPTEROUS FAUNA of New Caledonia and the New Hebrides has not been studied extensively. I have dealt elsewhere with the whole of the Rhopalocera (Viette, in press) and have prepared a catalogue of the known Heterocera from these regions (Viette, 1949).

In this paper are presented means of determining the known species of Noctuidae Catocalinae and descriptions of male and female genitalia which complete the original descriptions of these species. Material in the Department of Entomology of the National Museum of Paris has made this work possible.

The subfamily Catocalinae is well represented in New Caledonia and the New Hebrides as it is in all warm regions but, as an effect of the relative poorness of the fauna of these regions, there are not very many species. Most of these species are known from southern Asia and the other Pacific archipelagoes.

This subfamily is distinguished by having  $M_2$  well developed in the posterior wings (Noctuidae Quadrifidae),  $M_1$  and  $M_2$  more or less convergent toward their base, the middle tibiae with little spines, and the male retinaculum not having the shape of a small tongue. The venation is the same for the whole subfamily, for which reason it is described here:  $R_1$  is free; an areola is present;  $R_2$  arises from the apex of the areola as do  $R_5$  and the common stalk to  $R_3$  and  $R_4$ ;  $M_1$  arises from the superior angle of the medial cell or a little below;  $M_3$  and  $Cu_{1a}$  are separated from the inferior angle. In the pos-

terior wings, the medial cell extends through a third or a half of the wing;  $R$  and  $M_1$  arise from the same point, the superior angle of the medial cell;  $M_2$ ,  $M_3$ , and  $Cu_{1a}$  are plainly separated from the inferior angle.

## Key to the Genera

1. Metathoracic tibiae without spines . . . . . **Parallelia**  
Metathoracic tibiae with spines . . . . . 2
2. Prothoracic tibiae without spines . . . . . 3  
Prothoracic tibiae with spines . . . . . 8
3. Metathoracic tibiae with spines only between the medial and the terminal spurs . . . . . **Lagoptera**  
Metathoracic tibiae with spines only above the medial spurs . . . . . 4
4. Abdomen with hairs dorsally . . . . . 5  
Abdomen with scales dorsally . . . . . 6
5. Frons with a tuft of hairs dorsally . . **Anua**  
Frons without a tuft of hairs dorsally . . . . . **Achaea**
6. Posterior wings with a normal medial cell, extending to about the middle of the wing . . . . . **Mocis**  
Posterior wings with a small medial cell, not extending one-third of the length of the wing . . . . . 7
7. Antennae reaching the third quarter of the costa . . . . . **Chalciope**  
Antennae reaching the middle of the costa . . . . . **Grammodes**
8. Labial palpi with the second joint widened, spatulate . . . . . **Phyllodes**  
Labial palpi with the second joint normally formed . . . . . **Cocytodes**

<sup>1</sup>Department of Entomology, National Museum of Natural History, Paris. Manuscript received April 1, 1949.

Genus *COCYTODES* Guénée

*Cocytodes* Guénée, 1852, Spec. Gén. Lépid., Noct. 3: 41; Hampson, 1894, Fauna Brit. India, Moths 2: 485; 1913, Cat. Lépid. Phal. B.M. 12: 258; Gaede, 1938, in Seitz 11: 457 (type *coerulea* Gn.).

The proboscis is fully developed; the labial palpi are upturned, the second joint reaching the middle of the frons. The frons is smooth, clothed with flattened hairs and scales. The male antennae are simple. The thorax is clothed with hairs, without a crest. The tibiae are fringed with long hairs and have spines. The medial cell of the posterior wings extends about one-third of the wing.

One species only is known from these regions.

*Cocytodes coerulea* Guénée

Fig. 1a-c

*Cocytodes coerulea* Guénée, Spec. Gén. Lépid., Noct. 3: 41, pl. 13, fig. 10, 1852.

*Arcte caerulea* Guénée; Hampson, Fauna Brit. India, Moths 2: 486, fig. 272, 1894.

*Cocytodes caerulea* Guénée; Hampson, Cat. Lépid. Phal. B. M. 12: 259, fig. 33, 1913.

*Cocytodes coerulea* Guénée; Tams, Ins. of Samoa, Lépid. 4: 214, 1935.

*Cocytodes caerulea* Guénée; Gaede, in Seitz 11: 457, 1938.

*Cocytodes caerulea* Guénée; Viette, Pacific Science 3(4): 330, 1949.

Wingspread 86-88 mm.; length of the anterior wings 37-38 mm.

The head and the thorax are reddish brown, the abdomen is gray. In the male, there is a strongly sclerotized subrectangular plate in the middle of the tergite of the sixth segment which is transversely striped with black (Fig. 1b).

The anterior wings and thorax are reddish brown irrorated with bluish white scales, especially in the proximal part of the wing; the subbasal line is black, slightly oblique and sinuous; the orbicular spot is black and small;

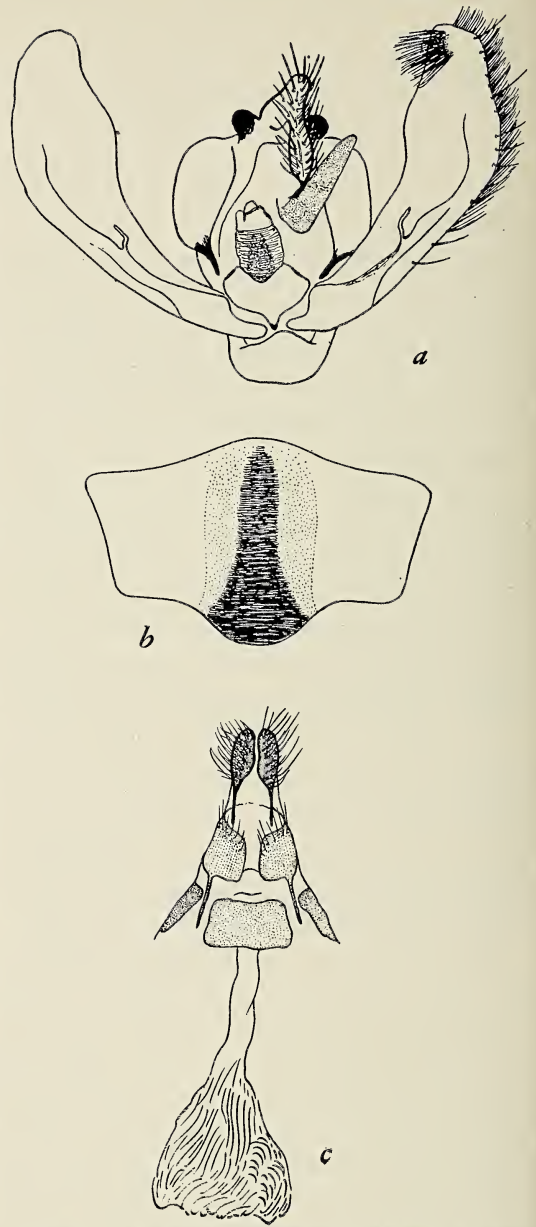


FIG. 1. *Cocytodes coerulea* Guénée: a, male genitalia; b, tergite of the eighth abdominal segment; c, female genitalia.

the reniform spot is well marked; the post-medial line is at first oblique with regard to the costa, then, on a level with  $M_3$ , becomes almost parallel to the latter, and finally reaches almost perpendicularly the inferior edge of the wing at its distal third; a large



part of the wing is dark, only the apex and the costal area are really reddish brown.

The posterior wings are blackish brown with purple tracings, which include a medial spot, a spot in the middle of the abdominal edge, a submarginal band, and a very narrow marginal band between  $Cu_{1b}$  and  $A_2$ .

The underside is lighter than the upper side. The anterior wings have an indication of a dark, transverse band edged with gray. The posterior wings have the tracings of the upperside well marked. The underside of the body is a dirty white.

**Genitalia ♂:** (Fig. 1a). The tergite of the sixth urite has a middle plate which is striped transversely (Fig. 1b). The tegumen is not much developed dorsally but carries laterally large processes which are suddenly thinned at their apex and end in a well-sclerotized and strongly colored point; the uncus is directed downward, it is hairy and sharp at its extremity; a scaphium is present; the vinculum is not much developed; the valvae are long, widened at the end; a small angular process is present about the middle of the dorsal edge of the sacculus; the juxta has almost the shape of a V; the penis is asymmetrical without cornuti.

**Genitalia ♀:** (Fig. 1c). Simple, the lobes of the oviporus are normal, with posterior apophyses; the eighth urite is unsclerotized in the medioventral area; the anterior apophyses are present; the ostium bursae is membranous as is the bursa copulatrix and the ductus bursae; the bursa copulatrix is ornamented with unsclerotized folds.

New Caledonia (Layard): Puerihouen (Quod), Canala (Delacour), Baraoua (Catala).

Loyalty Islands: Lifu (Whitmei).

New Hebrides (Mathew).

The species extends from India to Fiji and Samoa.

#### Genus PHYLLODES Boisduval

*Phyllodes* Boisduval, 1832, in Dumont d'

Urville, Voyage de l'Astrolabe, Lepid. 1: 246; Hampson, 1913, Cat. Lepid. Phal. B.M. 12: 389; Gaede, 1938, in Seitz 11: 470 (type *conspicillator* Cr.).

The proboscis is fully developed; the labial palpi are upturned; the second joint strongly widened, spatulate; the third joint small, normal, and dilated at its apex; the frons is smooth with a thick tuft of hairs; the antennae are filiform, reaching the middle of the costa. The thorax is clothed with hairs, without crest; the anterior wings have a strongly arched costa and the apex is slightly projected; in the posterior wings the medial cell does not extend as much as one third of the wing.

Only one species is of interest here.

#### *Phyllodes imperialis* Druce

Fig. 2a, b

*Phyllodes imperialis* Druce, Ann. and Mag. Nat. Hist. VI, 2: 241, 1888.

*Phyllodes imperialis* Druce; Hampson, Cat. Lepid. Phal. B.M. 12: 392, pl. CCXI, fig. 5, 1913.

*Phyllodes meyricki imperialis* Druce; Gaede, in Seitz 11: 470, pl. 48 b, 1938.

*Phyllodes imperialis* Druce; Viette, Pacific Science 3(4): 330, 1949.

Wingspread 159–175 mm.; length of the anterior wings 78–80 mm.

This is one of the most beautiful and largest of the moths from New Caledonia and the New Hebrides. The head, the thorax, and the abdomen are abundantly clothed with reddish gray hairs, with a light purple tint on the head, the patagiae, the inferior edge of the tegulae, and the abdomen.

The anterior wings are very wide, with the external margin and the inferior edge describing an arc of a circle; the costa is strongly arched in its apical part and the apex is slightly projected. The background color is rusty brown, more or less dark according to the specimens, with the variable tracings

more or less marked; the most variable tracing is the spot, without a distinct margin, which is found at the apex of the cell and the color of which varies from greenish white to a lighter shade of the background color. When they are well marked three transverse basal bands which are a little darker than the background color can be distinguished. There are also a slightly arched line which passes through the middle of the spot, and a line that starts at the apex runs almost parallel to the costa as far as  $Cu_{1b}$  and is there directed toward the inferior edge of the wing.

The space outside this line is lighter in color.

The posterior wings are black with a gray base. A lengthened spot, more or less bright pink, and a marginal band of white spots, typically triangular extend from the anal angle to the middle of the wing; each spot is found between veins.

The underside of the anterior wings is grayish, and the medial space is black with three whitish spots; the posterior wings are gray; the abdominal space is black with the pink spot; the body and the legs are gray.

Genitalia ♂: The tegumen is not strongly developed and has a narrow and thin uncus, first turned upward, then downward; the apex is sharp, the dorsal part of the uncus is clothed with bristles; the vinculum is rather broad, lengthened toward the frons but does not form a real saccus; the anal tube has a well-developed scaphium; the valvae (Fig. 2a) are subrectangular with a short expansion in the area of the external ventral angle; in the middle of the internal surface is a narrow process; the juxta is well developed and the penis is short, in part membranous in its apical region.

Genitalia ♀: The lobes of the oviporus are almost square; the posterior apophyses are normal; the eighth urite is entirely sclerotized, showing a differentiated plate in the middle ventral area above the ostium bursae; this, although not specialized, is clearly in-

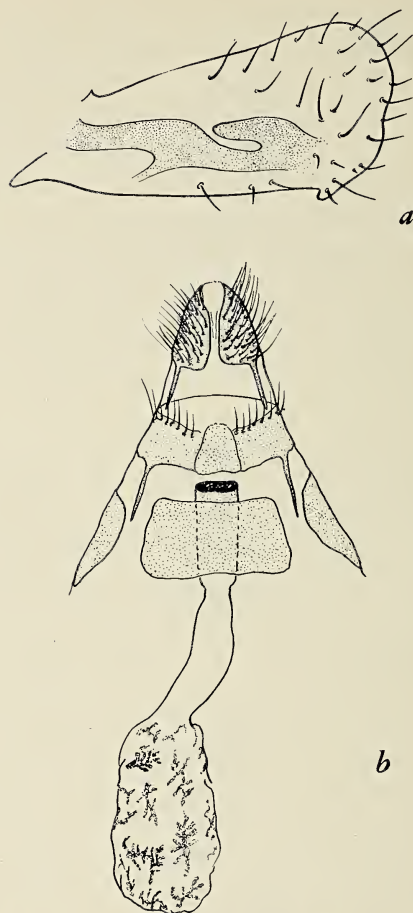


FIG. 2. *Phyllodes imperialis* Druce: a, right valva of male; b, genitalia of female.

dicated; the ductus bursae is highly sclerotized in the part connected with the ostium bursae; the bursa copulatrix is large, with small sclerotized marks (Fig. 2b).

New Caledonia (Millot).

Loyalty Islands (coll. de Joannis).

New Hebrides (Hampson l.c., Mrs. Pruvot, coll. de Joannis).

#### Genus LAGOPTERA Guénée

*Lagoptera* Guénée, 1852, Spec. Gén. Lépid., Noct. 3: 223; Hampson, 1913, Cat. Lepid. Phal. B.M. 12: 413; Gaede, 1938, in Seitz 11: 471 (type *honesta* Hb.).

The proboscis is fully developed; the labial



palpi are upturned, with the second joint lengthened to reach the vertex of the head; the third joint is short; the frons is smooth; the male antennae are ciliated. The thorax is clothed with hairs, without crest; the pro- and metathoracic tibiae of the males are fringed with long hairs; the prothoracic tibiae have no spines and the metathoracic tibiae have spines only between the medial and apical spurs. In the male, the underside of the posterior wings is entirely clothed with specialized scales (the androconiae of Hampson, 1913). The first segments of the abdomen carry tufts of hairs dorsally.

Only one species is known from this area.

### *Lagoptera miniacea* Felder

Fig. 3a-c

*Lagoptera miniacea* Felder, Reise Novara, Lepid., pl. 116, fig. 8, 1874.

*Lagoptera miniacea* Felder; Hampson, Cat. Lepid. Phal. B.M. 12: 416, 1913.

*Lagoptera miniacea* Felder; Tams, Ins. of Samoa, Lepid. 4: 214, 1935.

*Lagoptera miniacea* Felder; Gaede, in Seitz 11: 471, pl. 49 b, 1938.

*Lagoptera miniacea* Felder; Viette, Pacific Science 3(4): 330, 1949.

Wingspread 88–92 mm.; length of the anterior wings 43–45 mm.

The head and the thorax are reddish brown, more or less dark, the vertex with a little white line; the abdomen is light reddish brown anteriorly, the rest is pale red.

The background color of the anterior wings is that of the thorax irrorated with black and bluish white scales. At the extremity of the medial cell is found a black spot (the reniform spot), which is usually rather large, but which can become greenish white, or can be reduced to a little black point, or can even be absent; a basal dark line, lightly waved, exteriorly bent, is seen; the post-medial line is straight, dark; an indication of

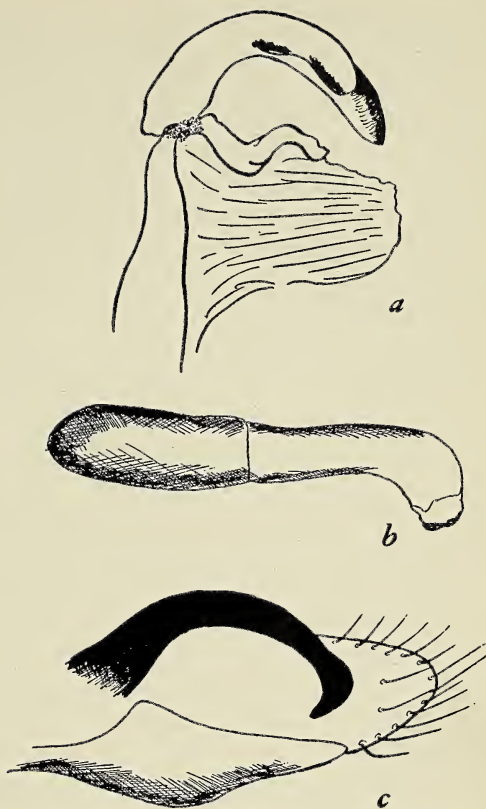


FIG. 3. *Lagoptera miniacea* Felder: a, tegumen, uncus, and anal tube; b, penis; c, right valva.

some black spots between  $M_1$  and  $M_2$  is sometimes seen in the marginal area.

The posterior wings are pale red with an indication of a black spot at the apex of the medial cell and a marginal black band with pale red on the external margin.

The underside of the wings is pale red; the legs are of this color with the underside black, irrorated with bluish white scales.

**Genitalia ♂:** The tegumen is not much developed, being almost indistinct; the uncus is strongly developed (Fig. 3a), bifid and asymmetrical, the right part being longer than the left part, these two parts rounded at their apex; the scaphium is very characteristic, highly sclerotized, carrying at its apex two lateral humps preceded by two dimples; the lateral dorsal parts of the ninth urite are narrow and long; the valvae (Fig. 3c) have

the costa well developed as a long and strong arm, upturned, widened at its apex, strongly sclerotized, and well colored; the valvula and the sacculus are recognizable but the sacculus is not distinct; the juxta is simple, in the shape of a lengthened plate; the penis (Fig. 3*b*) is long, with the rostral extremity widened and neatly indicated, with the distal apex upturned almost at 90 degrees and inclined toward the left side.

**Genitalia ♀ :** The lobes of the oviporus and the eighth urite are rather long but narrow as compared with the great development of the seventh urite. The lobes of the oviporus, as well as of the eighth urite, are abundantly clothed with bristles. The tergite of the seventh segment is strongly developed and covers the whole genitalia. The sternite of the same segment is modified; beneath the ostium bursae are found two triangular plates with their tops turned caudad: these plates lie on each side of the middle line; the ductus bursae is completely sclerotized and strongly colored; the ostium bursae is clearly marked and well visible; the bursa copulatrix is membranous and abundantly ornamented with unsclerotized folds.

New Hebrides: Mallicolo (Risbec), Tanna (Mrs. Pruvot).

Also from Solomon Islands, Fiji, and Samoa.

#### Genus ANUA Walker

*Anua* Walker, 1858, List Spec. Lepid. Ins. B.M. 15: 1788; Hampson, 1913, Cat. Lepid. Phal. B.M. 12: 425; Gaede, 1938, in Seitz 11: 472 (type *finifascia* Wlk.).

The proboscis is fully developed; the labial palpi are upturned, the second joint reaching the vertex of the head, the third joint being long and directed obliquely; the frons is smooth with a tuft of hairs; the male antennae are ciliated. The thorax has no crest. The venation is as described for the subfamily.

#### *Anua coronata* Fabricius

Fig. 4*a-c*

*Noctua coronata* Fabricius, Syst. Entom.: 596, 1775.

*Ophiusa coronata* Fabricius; Hampson, Fauna Brit. India, Moths 2: 502, 1894.

*Anua coronata* Fabricius; Hampson, Cat. Lepid. Phal. B. M. 12: 427, fig. 101, 1913.

*Anua coronata*. Fabricius; Collenette, Roy. Entom. Soc. London, Trans. 76: 476, 1928.

*Anua coronata* Fabricius; Tams, Ins. of Samoa, Lepid. 4: 214, 1935.

*Anua coronata* Fabricius; Gaede, in Seitz 11: 473, pl. 49 d, 1938.

*Anua coronata* Fabricius; Swezey, Bernice P. Bishop Mus. Bul. 189: 171, 1946.

*Anua coronata* Fabricius; Viette, Pacific Science 3(4): 330, 1949.

Wingspread 72–96 mm.; length of the anterior wings 37–42 mm.

The head and the thorax are reddish brown tinted with gray; the abdomen is yellow with the anterior edge of the segments black.

The anterior wings are reddish brown irrorated with gray and black; the antemedial line is brown and is obliquely curved in the middle of the cell; the orbicular spot is small and greenish gray; at the apex of the cell the reniform spot is typically greenish gray with some small black spots; a brownish shadow is found beneath the costa; the postmedial line is brown, oblique; the submarginal line is whitish; the spaces between the ante- and postmedial lines and the subterminal line and the external margin are of a lighter shade of the background color.

The posterior wings are yellow with a middle band and a submarginal black band from the costa to the anal fold.

The underside of the wings is yellow; in the anterior wings, in the area of the inferior angle, there is an indefinite black spot; the legs are yellow with the tarsi gray.

**Genitalia ♂ :** The dorsal part is characterized by its asymmetry (Fig. 4*a*); the tegu-



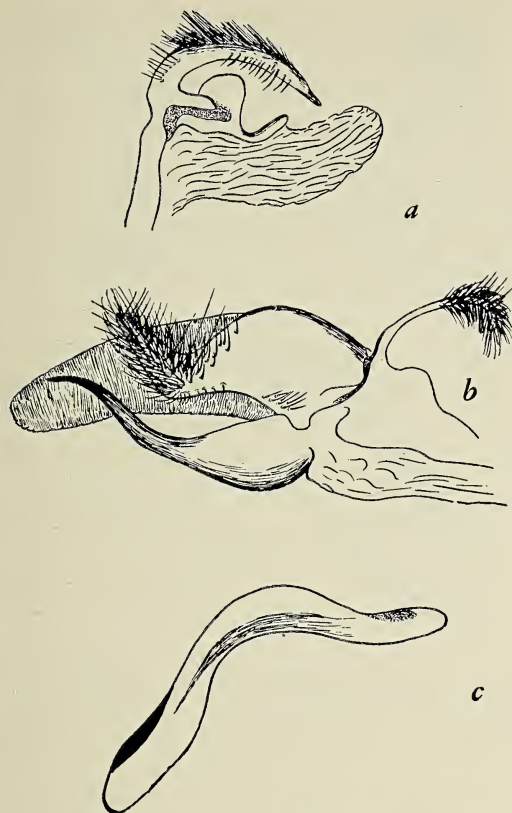


FIG. 4. *Anua coronata* Fabricius: a, tegumen, uncus, and anal tube; b, left valva; c, penis.

men is very narrow and the uncus is curved and clothed dorsally with bristles; on the right side, between the uncus and the anal tube, and arising from the latter, there is a vertically raised plate that is undoubtedly an excrescence of the scaphium; at the base of the uncus, toward the left, there is a kind of process directed backwards; moreover, as in most of the species still to be discussed, the valvae (Fig. 4b) carry, at their origin, a kind of long and narrow membranous bag abundantly clothed with bristles; there is a long costal arm, the sacculus is well developed and ends as a long, well-sclerotized and colored spur; the penis is at a right angle, speckled dorsally toward its apex (Fig. 4c).

**Genitalia ♀:** Resemble the genitalia of *Lagoptera miniacea* Feld., showing a large seventh segment and two lateral, triangular

plates at the middle line beneath the ostium bursae; however, it is distinguished from *L. miniacea* by a larger development of the eighth urite and by the ductus bursae which has first a sclerotized part, then a separate less sclerotized area, and finally an area in which there are some sclerotized longitudinal lines; the bursa copulatrix is membranous.

Hampson (1913) cites the following aberrations described as species by the old authors, because of the coloration of the reniform spot:

*magica* Hübner, Zutr. Exot. Schmett. 3: 32, figs. 535 and 536, 1827. The reniform spot is entirely black.

*leonina* Fabricius, Syst. Entom.: 596, 1775. The reniform spot is entirely green-gray.

*ancilla* Fabricius, Entom. Syst. 3(2): 17, 1794. The reniform spot is absent.

New Caledonia: Nouméa (coll. Fleutiaux).

New Hebrides: Pentecôte Island (Mrs. Pruvot).

This species has a geographical distribution that extends from India to the Society Islands.

#### Genus *ACHAEA* Hübner

*Achaea* Hübner, 1827, Verz. bekannt. Schmett., p. 269; Hampson, 1913, Cat. Lepid. Phal. B. M. 12: 496; Gaede, 1938, in Seitz 11: 479 (type *janata* L.).

The proboscis is fully developed; the labial palpi are upturned, the second joint reaching almost to the vertex, the third joint being short or moderately long; in the species described here, the antennae are filiform. The thorax has no crest; the prothoracic tibiae do not possess any spines, but the meso- and metathoracic tibiae do have them. The first segments of the abdomen bear tufts of hairs dorsally.

The genus contains numerous species occurring chiefly in the Ethiopian area, southern and southeastern Asia, and as far east as the

Marquesas archipelago. Two species are of interest here.

### Key to the species

1. The third joint of the labial palpi is almost as long as the second joint; the posterior wings have two medial white spots . . . . . *serva*  
The third joint of the labial palpi is very short; the posterior wings present a medial white band . . . . . *janata*

### *Achaea serva* Fabricius

Fig. 5a-d

*Noctua serva* Fabricius, Syst. Entom., p. 593, 1775.

*Ophiusa serva* Fabricius; Hampson, Fauna Brit. India, Moths 2: 495, 1894.

*Achaea serva* Fabricius; Hampson, Cat. Lepid. Phal. B.M. 12: 521, fig. 123, 1913.

*Achaea serva* Fabricius; Tams, Ins. of Samoa, Lepid. 4: 216, 1935.

*Achaea serva* Fabricius; Gaede, in Seitz 11: 480, pl. 52 d, 1938.

*Achaea serva* Fabricius; Swezey, Bernice P. Bishop Mus., Bul. 186: 172, 1946.

*Achaea serva* Fabricius; Viette, Pacific Science 3(4): 330, 1949.

Wingspread 62-80 mm.; length of the anterior wings 34-41 mm.

The head and the thorax are reddish brown and the abdomen brown-gray.

The anterior wings are red-brown, more or less dark; the antemedial line is dark, oblique, waved; a black spot is in the middle of the medial cell; the reniform spot is small, occasionally even indistinct, and sometimes only a blackish shadow can be seen in its place; the medial line is slightly sinuous, curved exteriorly on a level with the medial cell; the postmedial line is dark and sinuous; the marginal area is of the background color, but darker, with an indication of a subterminal line; sometimes there is a series of black spots along the external margin.

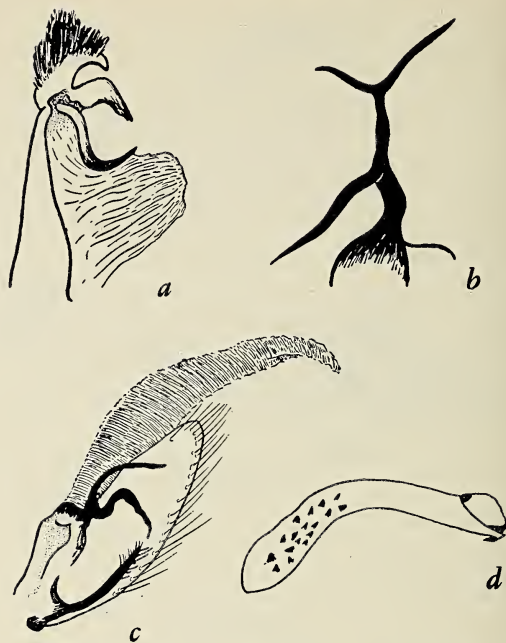


FIG. 5. *Achaea serva* Fabricius: a, tegumen, b, asymmetrical formation of the costal part of the left valva; c, right valva; d, penis.

The posterior wings are black with a purplish blue reflection and on each wing there are five white spots, two in the middle, and three near the margin, at the extremity of costa, of  $M_2$ , and between  $Cu_{1b}$  and A 1.

The underside of the four wings is grayish white, irrorated with black scales; in the anterior wings, there are a white spot on the discocellular veins and a large black spot in the area of the inferior angle of the wing; in the posterior wings there is a brown submarginal band which becomes black toward the anal angle.

**Genitalia ♂:** The tegumen is very narrow and carries an important excrescence raised vertically, curved at its end, and clothed dorsally with strong bristles (Fig. 5a); the lateral parts of the ninth urite are progressively narrowed dorsally; the uncus is curved ventrally at its apex; the anal tube carries a very well-developed scaphium; at their base the valvae (Fig. 5c) have a long bag abundantly clothed with bristles, and they are



simple, oval, with a distinct sacculus; in the proximal part of the dorsal area they have an asymmetrical formation that arises from the costa (Fig. 5*b* and *c*); between this part and the sacculus is the valvula; the penis is curved, with a great many cornuti and a point at its apex on the ventral side (Fig. 5*d*).

**Genitalia ♀:** The lobes of the oviporus are small, lengthened, and clothed with bristles, as is the eighth urite which is well developed; the anterior and posterior apophyses are present; the tergite of the seventh segment is very well developed; the ostium bursae is in the middle of a sclerotized area which extends caudad in the shape of a band that joins the eighth segment; beneath the ostium bursae is a plate that works like a clapper and is homologous with the two fused triangular plates described in the two previous species; this plate has a medial notch in the shape of a V on its caudal edge; the first part of the ductus bursae is sclerotized, becoming less heavily sclerotized; the bursa copulatrix is, in part, also lightly sclerotized.

New Caledonia (Marie, Quod): Mont Mou (Quod), Western Coast (Risbec).

Loyalty Islands: Lifu (Marshall).

New Hebrides: Vaté (Turner).

Also in Samoa.

### *Achaea janata* Linné

Fig. 6*a-c*

*Geometra janata* Linné, Syst. Natur., ed. 10, p. 527, 1758.

*Achaea janata* Linné; Rebel, Hamb. Wiss. Anstalt, Jahrb., 2 Beiheft, 32: 128 and 149, 1915.

*Achaea janata* Linné; Collenette, Roy. Entom. Soc. London, Trans. 76: 477, 1928.

*Achaea janata* Linné; Tams, Ins. of Samoa, Lepid. 4: 216, 1935.

*Achaea janata* Linné; Swezey, Bernice P. Bishop Mus. Bul. 186: 171, 1946.

*Achaea janata* Linné; Viette, Pacific Science 3(4): 331, 1949.

*Noctua melicerta* Drury, Ill. Exot. Ins. 1: 42, pl. 23, fig. 1, 1770.

*Ophiusa melicerta* Drury; Hampson, Fauna Brit. India, Moths 2: 494, 1894.

*Achaea melicerta* Drury; Hampson, Cat. Lepid. Phal. B.M. 12: 536, fig. 124, 1913.

*Achaea melicerta* Drury; Gaede, in Seitz 11: 480, pl. 52 f, 1938.

*Achaea pentasema* Prout; Ann. and Mag. Nat. Hist. IX, 3: 181, 1919.

*Achaea pentasema* Prout; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 52–60 mm.; length of the anterior wings 27–32 mm.

The head and the thorax are gray, occasionally mixed with reddish brown; the abdomen is gray.

The anterior wings typically have a grayish brown background color with a basal black streak well indicated only in the costal half, and an antemedial black line, waved, oblique; two black spots are on a level with the discocellular veins; then comes a blackish brown space, between the postmedial and submarginal lines; from the costa a dark line extends toward the apex; along the external margin there is a series of black spots. This typical coloration is very variable; the background color can be darker, with the brownish black tracings sometimes being less evident, sometimes lacking completely.

The posterior wings are blackish brown with a purplish blue reflection; the base of the wings is lighter; a medial white band and three marginal spots are placed at the apex of the costa, on a level with  $M_2$  and at the anal angle.

**Genitalia ♂:** As in *A. serva* the tegumen has a dorsal excrescence which is densely clothed with bristles (Fig. 6*a*) and becomes rostral distad of the excrescence; at the apex a sclerotized blade emerges from the bristles; the uncus has a normal shape terminating in a point; there is a well-developed scaphium covered at the extremity with fine hooks; the

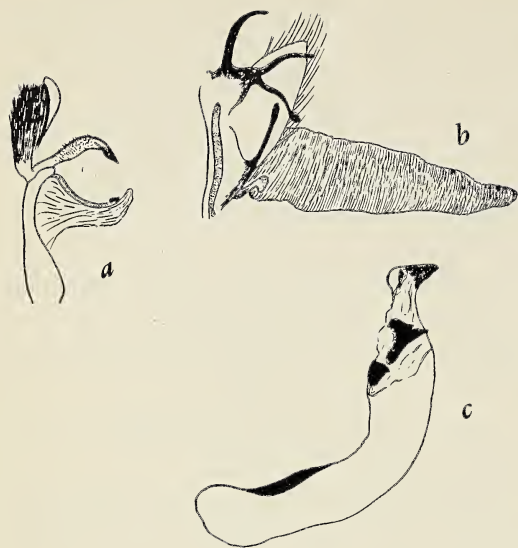


FIG. 6. *Achaea janata* Linné: *a*, tegumen, uncus, and anal tube; *b*, right valva; *c*, penis.

lateral parts of the ninth segment are narrow; the valvae (Fig. 6*b*) have a spur-shaped well-defined sacculus; the superior or costal part of the valvae is reduced here to an area carrying three long, strongly sclerotized, well-colored processes; between them can be seen a simple valvula; at the base of the valvae there is a long, membranous bag, covered with many bristles as there is in *A. serva*; the penis (Fig. 6*c*) is dorsally curved, asymmetrical, pointed, and well colored at its apex, and has a vesica with many thick cornuti.

**Genitalia ♀:** Similar to *A. serva* but distinguished by the shape of the sclerotized area above the ostium bursae, which is here fully developed, extends full width to the eighth urite and is inflected on the edges, forming a sort of pocket at the depth of which the ostium bursae opens; the clapper, placed underneath the copulatory opening, is almost square, with the medial notch of the caudal edge rounder; the bursa copulatrix is less sclerotized.

New Caledonia (Marie): Nouméa (Quod, Risbec, Catala).

New Hebrides: Vaté, Port Vila (Kowalsky).

This species extends from the Persian Gulf to the Marquesas Islands.

#### Genus *PARALLELIA* Hübner

*Parallelia* Hübner, 1827, Verz. bekannt. Schmett., p. 269; Hampson, 1913, Cat. Lepid. Phal. B.M. 12: 551; Gaede, 1938, in Seitz 11: 481 (type, *bistriaris* Hb.).

The proboscis is fully developed; the labial palpi are upturned; the second joint is on a level with the vertex and lightly scaled; the frons is smooth with a tuft of hairs above; the male antennae are ciliated; the pro- and metathoracic tibiae are generally without spines.

#### Key to the species

1. Anterior wings with the costa showing a light lobe before its middle . . . *redunca*  
Anterior wings with the costa not showing a similar lobe . . . . . 2
2. Anterior wings with the postmedial line toothed beneath  $M_1$  . . . . . *prisca*  
Anterior wings with the postmedial line not toothed beneath  $M_1$  . . . . . *joviana*

#### *Parallelia redunca* Swinhoe

Fig. 7*a-d*

*Ophiusa redunca* Swinhoe, Cat. Lepid. Heter. Mus. Oxon. 2: 141, 1900.

*Parallelia redunca* Swinhoe; Hampson, Cat. Lepid. Phal. B.M. 12: 553, fig. 131, 1913.

*Parallelia redunca* Swinhoe; Gaede, in Seitz 11: 481, pl. 53 a, 1938.

*Parallelia redunca* Swinhoe; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 61–64 mm.; length of the anterior wings 28–29 mm.

The head and thorax are reddish brown, the tegulae have a whitish apex; the legs are clothed with gray hairs which are yellow at their origin.

The anterior wings have a background



color of reddish brown, more or less tinged with purplish gray, chiefly in the costal half. There are three transverse lines; the antemedial is the most distinct, and is dark, edged laterally by lighter color; there is an indication of a dark medial line; the postmedial line is formed, as is the antemedial, but at first it is perpendicular to the costa, then is deeply curved inward; the costal part, which is

darker in color, does not pass this line; the space exterior to the postmedial line is lighter in color, with, in the male, a black spot on a level with  $M_1$ ; there is also a marginal series of little black points; the cilia are dark.

The posterior wings are blackish gray with an indication of gray bands, in the middle and at the anal angle, both perpendicular to the abdominal edge.

The underside is gray-white with the postmedial line only slightly indicated.

Genitalia ♂: It is narrow and high; the lateral parts of the ninth urite are narrow dorsally; the uncus (Fig. 7a) is strongly modified, consisting of plates raised vertically, abundantly clothed with bristles on the rostral side and carrying a strong dorsal tooth on the caudal side; the scaphium is well constituted; the vinculum is reduced; the valvae (Fig. 7b) are rather complex, having a well-defined sacculus; there is a simple valvula, which is slightly pointed and turned at its apex; the costal part is strongly denticulated with a sharp, sclerotized and well-colored apex; laterally, at the basis of the valvae, is a membranous bag clothed with bristles; the penis (Fig. 7c) is strongly curved dorsally in its rostral part, its caudal part is very much sclerotized; there are no cornuti.

Genitalia ♀: The lobes of the oviporus are but slightly developed as are the posterior apophyses, which are hardly sclerotized; the eighth urite shows short and clearly visible anterior apophyses, but the development of the seventh tergite is characteristic; its edges, on the ventral side, are folded, thus delimiting a kind of chamber closed by a clapper that has the shape of a lengthened trapezoid and whose caudal edge is slightly curved in the middle; the ostium bursae opens at the end of a well-colored and highly sclerotized conduit (Fig. 7d); the ductus bursae and the bursa copulatrix are membranous.

New Hebrides (coll. de Joannis).

Hampson (1913) cites this species from Dutch New Guinea and Queensland.



FIG. 7. *Parallelia redunca* Swinhoe: a, tegumen, uncus, and anal tube; b, right valva; c, penis; d, clapper and ostium bursae.

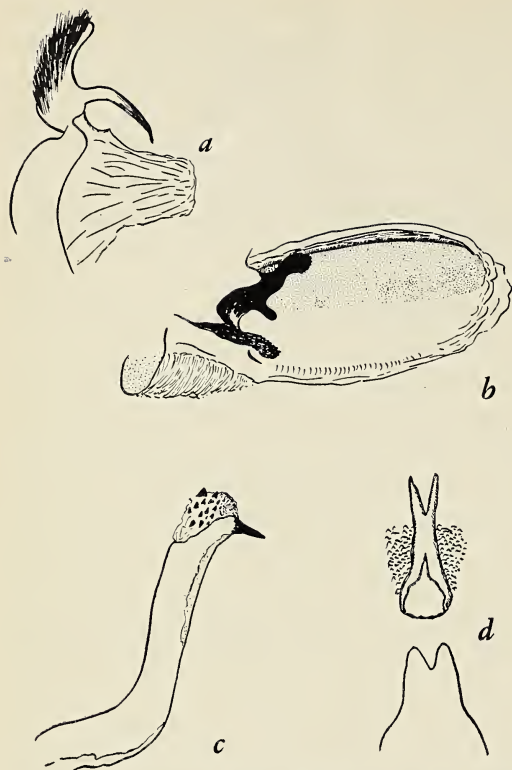


FIG. 8. *Parallelia prisca* Walker: *a*, tegumen, uncus, and anal tube; *b*, right valva; *c*, penis; *d*, clapper and ostium bursae.

### *Parallelia prisca* Walker

Fig. 8a-d

*Ophisma prisca* Walker, List Lepid. Ins. B.M. 14: 1385, 1858.

*Parallelia prisca* Walker; Hampson, Cat. Lepid. Phal. B.M. 12: 558, pl. CCXIX, fig. 10, 1913.

*Parallelia prisca* Walker; Tams, Ins. of Samoa, Lepid. 4: 217, 1935.

*Parallelia prisca* Walker; Gaede, in Seitz 11: 482; pl. 53 b, 1938.

*Parallelia prisca* Walker; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 60-65 mm.; length of the anterior wings 28-30 mm.

The head and thorax are reddish brown, the legs are gray with the tarsi yellowish gray; the abdomen is grayish brown.

The anterior wings have a dark reddish brown background color; the subbasal line, which is clearly indicated in the costal half, is red-brown, defined on each side by reddish ochre; the oblique and sinuous antemedial line is red-brown defined on each side by reddish ochre; there is a white spot, more or less marked, in the middle of the medial cell; the reniform spot is small, defined by a dark edging; there is a series of dark red-brown lines curved outwardly but becoming perpendicular at the inferior edge of the wing; these lines grow dimmer and dimmer in the marginal area till they are almost unicolored dark reddish brown; the external margin of the wing is a purplish pale gray; in the apical area there is an oblique white streak partly edging a chocolate brown apical spot.

The posterior wings are dark gray with purplish white-gray medial and marginal bands; none of these bands reaches the costa.

The underside of the wings is more or less dark gray with slightly purplish reflections at the basis of the posterior wings and is irrorated with black scales.

Genitalia ♂: The dorsal parts of the ninth urite are slightly incurved; between the much reduced tegumen and the typical uncus is a strong plate (Fig. 8a) vertically raised and abundantly clothed with bristles in its rostral part; the valvae (Fig. 8b) are oval, and differ from those of the other two species in having a kind of clavus toward the base and, in the costal half, a sclerotized modified formation; the penis (Fig. 8c) is highly upturned, with a strong point at its apex, and shows many cornuti.

Genitalia ♀: Similar to the female genitalia of *P. redunca* but can be distinguished easily by the shape of the process on the conduit which is contiguous with the ostium bursae, and by the shape of the clapper whose caudal edge is deeply notched in its middle (Fig. 8d).

New Hebrides (coll. de Joannis).



Loyalty Islands (coll. Mus. Hist. Nat. Paris).

Also from Samoa, Tonga, and Fiji.

*Parallelia joviana* Stoll

Fig. 9a-d

*Noctua joviana* Stoll, Pap. Exot. 4: 237, pl. 399, fig. B, 1782.

*Ophiusa joviana* Stoll; Hampson, Fauna Brit. India, Moths 2: 499, 1894.

*Parallelia joviana* Stoll; Hampson, Cat. Lepid. Phal. B.M. 12: 571, fig. 132, 1913.

*Parallelia joviana* Stoll; Gaede, in Seitz 11: 485, pl. 53 f, 1938.

*Parallelia joviana* Stoll; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 43–46 mm.; length of the anterior wings 20–22 mm.

The head and thorax are purple-gray, more or less dark, while the abdomen is gray; the labial palpi and the underside of the body and the legs are fawn-gray.

The anterior wings have a brownish gray background color; in the proximal third of the wing can be seen the red-brown sub-basal line, laterally edged by ochre-brown; this subbasal line does not extend beyond the costal half of the wing and there is an ante-medial line, formed in the same manner, slightly curved toward the inside; the post-medial line is whitish gray, at first almost perpendicular to the costa, then becoming undulate. Inward of this postmedial line is a large dark brown area, bordered by a semi-circular line, edged with a whitish gray space; the space between the postmedial line and the external margin is grayish brown with a dark brown spot at the apex, preceded, near the costa, by purplish gray. There is a marginal series of black dots.

The posterior wings are blackish gray, lighter basally and with the margin purplish gray in the abdomen angle area.

The underside is ochre-brown irrorated with darker spots.

Genitalia ♂: The tegumen is very narrow and almost indistinct, with a long, strongly downcurved, and well-developed saccus (Fig. 9a); the uncus has a lateral tuft of bristles at its base; there is a well-developed scaphium; the vinculum is reduced; the valvae (Fig. 9b) are modified; the costal part of the valva is changed into a long widened arm indented at its apex; the sacculus is long, filiform, bristled at its apex; the valvula is fully developed, clothed with bristles on its edges; lateral to the valva can be seen a long membranous bag, abundantly clothed with

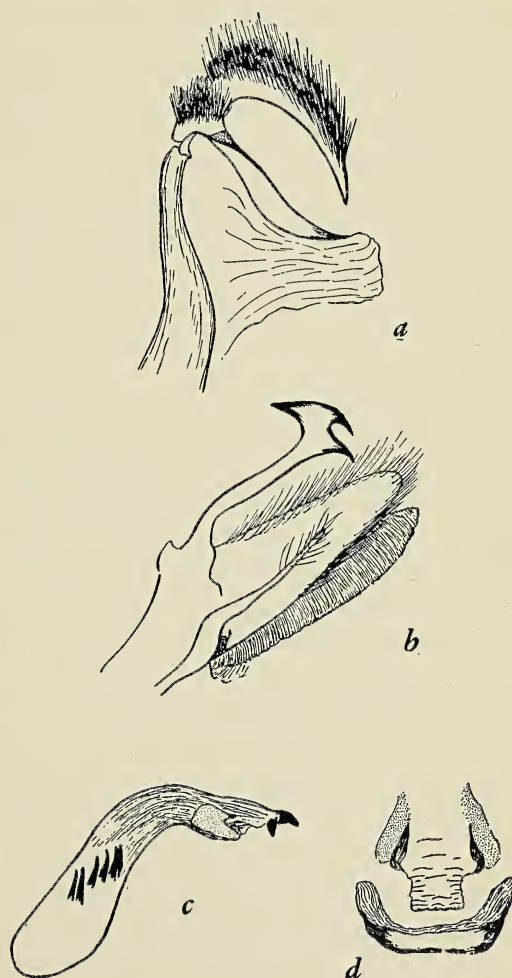


FIG. 9. *Parallelia joviana* Stoll: a, tegumen, uncus, and anal tube; b, right valva; c, penis; d, clapper and ostium bursae.

bristles; the penis is curved at a right angle, is asymmetrical, and has cornuti (Fig. 9c).

Genitalia ♀: The female genitalia are distinguished from those of the other species by the shape of the ostium bursae and of the clapper; the clapper is thick, showing folds of stronger sclerotization, and is semicircular (Fig. 9d).

Loyalty Islands: Lifu (Hampson, 1913).

New Hebrides (Paris Museum, coll. de Joannis).

The species extends from India to the New Hebrides.

#### Genus GRAMMODES Guénée

*Grammodes* Guénée, 1852, Spec. Gén. Lépid., Noct. 3: 275; Hampson, 1913, Cat. Lepid. Phal. B.M. 13: 13; Gaede, 1938, in Seitz 11: 489 (type *geometrica* F.).

The proboscis is fully developed, the labial palpi are upturned; the second joint reaches the vertex of the head and is slightly scaly; the third joint is small and oblique; the frons is smooth with tufts of hairs above; the male antennae are ciliated. The thorax has no crest, the prothoracic tibiae are not spined, but the metathoracic tibiae have spines at their base. The abdomen is clothed with scales, and is without a crest. The anterior wings have a rounded apex and the medial cell of the posterior wings reaches a third of the length of the wings.

Only one species is known from this area.

#### *Grammodes oculicola* Walker

Fig. 10a-d

*Grammodes oculicola* Walker, List Spec. Lepid. Ins. B.M. 14: 1446, 1858.

*Grammodes oculicola* Walker; Hampson, Cat. Lepid. Phal. B.M. 13: 15, 1913.

*Grammodes oculicola* Walker; Collenette, Roy. Entom. Soc. London, Trans. 76: 477, 1928.

*Grammodes oculicola* Walker; Gaede, in Seitz 11: 489, pl. 54 e, 1938.

*Grammodes oculicola* Walker; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 34-42 mm.; length of the anterior wings 16-19 mm.

The head, labial palpi, thorax, and abdomen are gray, the labial palpi and the abdomen being lighter in color.

The anterior wings have a brown background color with two rather wide creamy-white oblique bands; the more basal band starts from the basal third of the costa and reaches the middle of the inferior edge of the wing; the second band starts from the distal third of the costa; it is parallel to the first band till  $Cu_{1a}$  is reached, then it is suddenly narrowed, changes direction and reaches the inferior margin of the wing at a point where it almost touches the first band; in the inferior angle there is a black spot margined anteriorly and posteriorly by a fine bluish white streak; along the external margin there is a more or less well-defined ochre-brown band; the cilia are gray in the proximal half and white in the distal half.

The posterior wings are blackish gray with a rather wide medial white band perpendicular to the costa, that is turned at its apex and does not reach the anal angle; the cilia are white except on a level with the costa and  $M_3$ , where they are black; they become gray in the area of the anal angle.

The underside of the wings is blackish gray, white basally, and with well-marked white tracings.

Genitalia ♂: The tegumen is indistinct, dorsally there is an uncus (Fig. 10a) which has a tuft of long, vertically raised bristles laterally, and a similar tuft dorsally and ventrally; the scaphium is well distinguished and sclerotized; a little above the articulation of the valvae, from the dorsal part of the ninth urite, two lateral extensions arise; the valvae (Fig. 10b), although distinct, are simple; the costa and the sacculus are well developed, and have the shape of long, highly sclero-



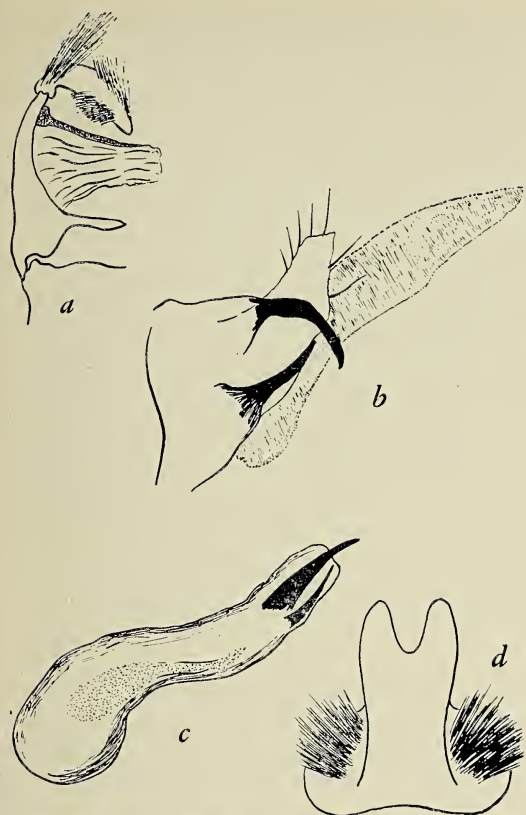


FIG. 10. *Grammodes oculicola* Walker: *a*, tegumen, uncus, and anal tube (v—valva); *b*, right valva; *c*, penis; *d*, clapper.

tized, well-colored processes pointed at their apex; the valvula has its edges notched and is clothed with bristles; laterally there is a long, membranous bag abundantly clothed with scales; the penis is rather large (Fig. 10*c*), is globular at one end, and has two long cornuti.

**Genitalia ♀:** The lobes of the oviporus are small with rather long posterior apophyses; the eighth segment is reduced; the tergite of the seventh segment is always fully developed; the characteristic piece, the clapper, which closes the chamber where the ostium bursae opens, is formed by a long medial piece which is deeply notched at its apex and flanked at its base by two lateral parts having tufts of bristles (Fig. 10*d*).

New Caledonia: Nouméa (Paris Museum, coll. Fleutiaux).

Loyalty Islands: Lifu (coll. Paris Museum).

#### Genus *CHALCIOPE* Hübner

*Chalciope* Hübner, 1827, Verz. bekannt. Schmett., p. 268; Hampson, 1913, Cat. Lepid. Phal. B.M. 13: 26; Gaede, 1938, in Seitz 11: 490 (type *cephise* Cr.).

The proboscis is fully developed; the labial palpi are upturned; the second joint, which reaches the vertex of the head, is lightly scaled; the third joint is short, and is clothed with raised scales beneath; the frons is smooth with tufts of hairs above; the male antennae are ciliated. The thorax is without crest, the meso- and metathoracic tibiae have long hairs on their inner side and are spined, the prothoracic tibiae are not spined. The abdomen is smooth without crest. The anterior wings have a slightly projected apex. In the males the basal area of the underside of the wings is clothed with specialized hairs.

#### *Chalciope cephist* Cramer

Fig. 11*a-c*

*Noctua cephist* Cramer, Pap. Exot. 3: 59, pl. 227, fig. C, 1779.

*Trigonodes cephist* Cramer; Hampson, Fauna Brit. India, Moths 2: 528, 1894.

*Chalciope cephist* Cramer; Hampson, Cat. Lepid. Phal. B.M. 13: 30, fig. 6, 1913.

*Chalciope cephist* Cramer; Tams, Ins. of Samoa, Lepid. 4: 217, 1935.

*Chalciope cephist* Cramer; Gaede, in Seitz 11: 490, pl. 54 f, 1938.

*Chalciope cephist* Cramer; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 53–61 mm.; length of the anterior wings 26–29 mm.

The head, the thorax, and the abdomen are more or less light ochre-gray; the labial palpi and the frons are darker; the legs are ochre.

The anterior wings are dark brown with a wide costal, marginal band and, at the inferior edge, are cream-white irrorated with

black scales; the dark brown space thus defined is divided by a wide, oblique band extending from the middle of the costa to the external inferior angle; there is a submarginal line of black spots in the light marginal space.

The posterior wings are blackish gray with a yellowish white basal spot and a medial space both poorly defined; the area of the anal angle is also yellowish white but somewhat grayer.

The underside of the wings is ochre irrorated with black scales. In the anterior wings there is a black spot in the distal half of the wing preceded by a yellowish white one.

Genitalia ♂: The tegumen is indistinct,

but there is a well-developed uncus (Fig. 11*a*) which is acute apically and bears a long tuft of bristles both dorsally and ventrally; the scaphium is present but is almost perpendicular to the uncus; the anal tube is short and rather low with regard to the uncus; the valvae (Fig. 11*b*) show little development of the costal part and saccus; the apex is rounded, clothed with long, strong bristles; the internal side of the valva has a long, narrow process, well sclerotized and colored at its end. (Should it be considered as a harpe?) The juxta is highly developed and, laterally to the penis, shows two triangular parts clothed with small prickles; the penis is curved at its apex and is speckled (Fig. 11*c*).

New Hebrides: Mallicolo (Risbec).

The species is also found in Samoa.

#### Genus *MOCIS* Hübner

*Mocis* Hübner, 1827, Verz. bekannt. Schmett., p. 267; Hampson, 1913, Cat. Lepid. Phal. B.M. 13: 76; Gaede, 1938, in Seitz 11: 493 (type *undata* F.).

The proboscis is fully developed; the labial palpi are upturned; the second joint reaches the vertex of the head and is slightly scaly; the third joint is short, oblique; the frons is smooth; the male antennae are ciliated. The thorax, without crest, is clothed with scales; the prothoracic tibiae are not spined; the metathoracic tibiae are spined. The abdomen is clothed with scales, without crest. In the anterior wings, the apex is slightly projected; the venation is similar to that of the species last described.

#### Key to the species

1. Anterior wings with two parallel, rather wide, transverse bands . . . . . *trifasciata*  
Anterior wings with an oblique transverse band, narrower, starting from the apex . . . . . *frugalis*

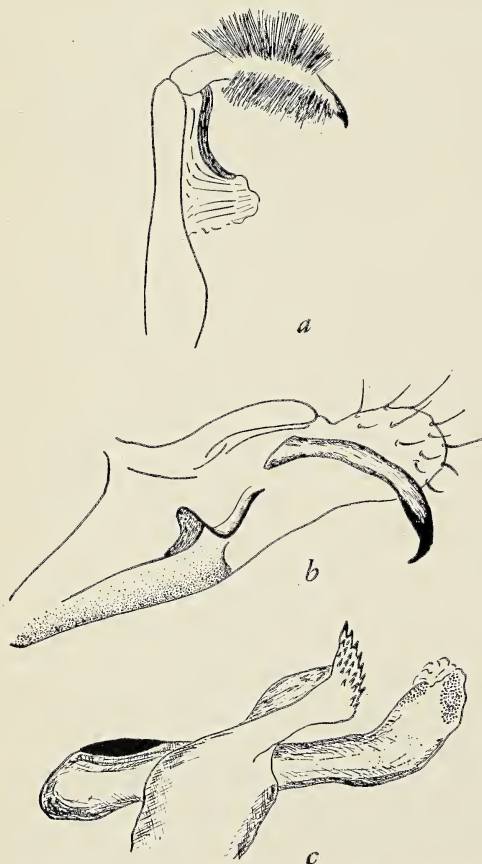


FIG. 11. *Chalciopse cephise* Cramer: *a*, tegumen, uncus, and anal tube; *b*, right valva; *c*, penis and juxta.



**Mocis frugalis** Fabricius

Fig. 12a-c

*Noctua frugalis* Fabricius, Syst. Entom., p. 601, 1775.

*Remigia frugalis* Fabricius; Hampson, Fauna Brit. India, Moths 2: 527, 1894.

*Mocis frugalis* Fabricius; Hampson, Cat. Lepid. Phal. B. M. 13: 87, fig. 23, 1913.

*Mocis frugalis* Fabricius; Collenette, Roy. Entom. Soc. London, Trans. 76: 478, 1928.

*Mocis frugalis* Fabricius; Tams, Ins. of Samoa, Lepid. 4: 218, 1935.

*Mocis frugalis* Fabricius; Gaede, in Seitz 11: 493, 1938.

*Mocis frugalis* Fabricius; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 33–36 mm.; length of the anterior wings 18–19 mm.

The head, thorax, and abdomen are gray, the head and thorax being darker than the abdomen; the legs are gray mixed with ochre.

The anterior wings have a background color of dark gray mixed with black scales; the costa and the apex are a darker, blackish gray. The coloration of the species is rather variable; typically there is: a reniform spot slightly marked on the discocellular veins; a variable, elongate, medial, ochre-brown spot above the anal vein; a transverse, oblique, ochre-brown band starting from the apex and reaching the distal third of the inferior margin; within this band is a fine black line edged with cream-white; there is a submarginal series of black spots, each spot being on a vein, and these spots are bounded by a fine ochre-brown line; the external margin is ornamented with a fine black line, and a black spot is found at the proximal third of the inferior edge.

The posterior wings are blackish gray, with the base and a slightly medial band lighter in color.

The underside is blackish gray, with the marginal parts darker in color.

**Genitalia ♂:** The tegumen is very small, almost indistinct; the uncus (Fig. 12a) is typical; there is a scaphium; the lateral parts of the ninth urite are narrow; the valvae (Fig. 12b) are complicated, showing a strong process dorsally, a series of teeth ventrally, and a kind of long, colored, and strongly sclerotized spur medially; the penis is curved; the juxta is laterally lengthened (Fig. 12c) by two formations that meet dorsad of the penis; the part thus formed is very sharp and bears a number of sclerotized teeth.

**Genitalia ♀:** The lobes of the oviporus and the parts of the eighth segment are normal with anterior and posterior apophyses; the tergite of the seventh segment is always well developed, but here the lateral edges of the ventral side fuse with the part called the clapper in the preceding species, and thus only the apex remains free; hence the ostium bursae opens at the bottom of a completely enclosed chamber; the ductus bursae is first sclerotized, then membranous, then sclero-

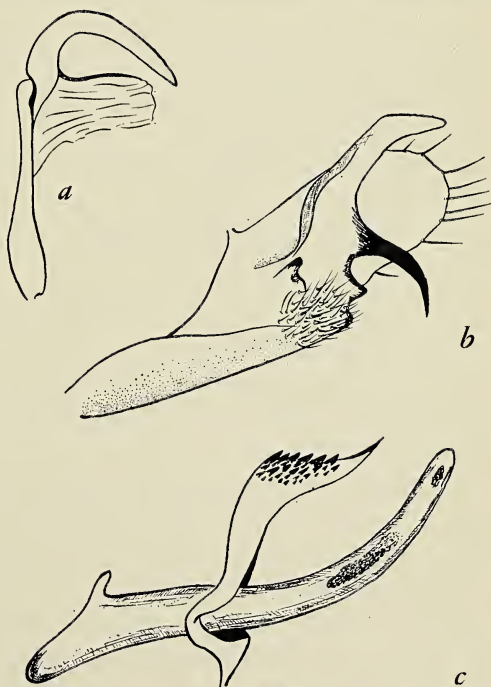


FIG. 12. *Mocis frugalis* Fabricius: a, tegumen, uncus, and anal tube; b, right valva; c, penis and juxta.

tized again; the bursa copulatrix has a slightly sclerotized part and a membranous part.

New Caledonia (Marie): Canala (Delacour), Nouméa, Voh (Catala).

This species has a wide geographical range extending over the Ethiopian region, the Indo-Australian area, and the Pacific islands (Carolines, Marshall, Gilbert, Ellice, Fiji, Samoa) to the Marquesas Islands and the Tuamotu Archipelago.

The specimens from New Hebrides and the Loyalty Islands, indicated in my Catalogue (1949), actually belong to the next species.

### *Mocis trifasciata* Stephens

Fig. 13a-c

*Catephia trifasciata* Stephens, Ill. Brit. Entom. Haust. 3: 128, 1829.

*Mocis trifasciata* Stephens; Hampson, Cat. Lepid. Phal. B.M. 13: 93, pl. CCXXIII, fig. 23, 1913.

*Mocis trifasciata* Stephens; Collenette, Roy. Entom. Soc. London, Trans. 76: 478, 1928.

*Mocis trifasciata* Stephens; Tams, Ins. of Samoa, Lepid. 4: 218, 1935.

*Mocis trifasciata* Stephens; Gaede, in Seitz 11: 493, pl. 55 c, 1938.

*Mocis trifasciata* Stephens; Viette, Pacific Science 3(4): 331, 1949.

Wingspread 45-48 mm.; length of the anterior wings 21-23 mm.

The head and thorax are brownish gray, the abdomen is gray; the legs are gray mixed with ochre-brown.

The anterior wings are gray irrorated with black scales and have a slight bluish reflection. Typically, a rather wide transverse band can be seen, which is ochre-brown at the basal third of the wing; interiorly it has a cream line; toward the exterior it is poorly defined and mixes with the background color; another ochre-brown transverse band is at the distal third of the wing; this band is wider

at the costa than at the inferior edge, and it too is very badly defined, having lighter and darker parts; exterior to it is a line of black spots; the marginal band is a little darker than the background color; the margin is a thin black line.

The posterior wings are ochre-brown-gray, with the abdominal margin, a medial band, and some parts along the external margin creamy white.

The underside is ochre with darker distal parts.

Genitalia ♂: The lateral dorsal parts of the ninth urite are narrow; the tegumen is indistinct and the uncus is typical with a small beak at the apex (Fig. 13a); the scaphium is present; the valvae (Fig. 13b) are subrectangular with a small lengthening at the dorsal apex; neither the costa nor the sacculus is well defined; a short process starts from the internal surface and widens



FIG. 13. *Mocis trifasciata* Stephens: a, tegumen, uncus, and anal tube; b, right valva; c, penis and juxta.



apically into a wide plate which carries raised extensions both dorsally and ventrally, the ventral being upturned; the penis is straight, and is carried by a juxta lengthened by two long plates, lateral to the penis (Fig. 13c).

Genitalia ♀: These have the same form as those of *Mocis frugalis* F., but can be distinguished by their larger anterior and posterior apophyses, and particularly by a greater specialization of the chamber where the ostium bursae opens; the lateral ventral edges of the seventh tergite come to a level with the ductus bursae upon which, beneath, is fused a lengthened part, which is curved at its caudal edge and is homologous to the part called the clapper in the other species but which here does not have the same function. Thus the ostium bursae is pushed backwards; the ductus bursae is longer, sclerotized; the bursa copulatrix is membranous.

New Caledonia: Canala (Delacour), Nouméa (Catala).

Loyalty Islands (coll. Donckier, Paris Museum).

New Hebrides: Mallicolo (Risbec); Tanna (Aubert de la Rüe); Vaté, Port Vila (Risbec).

The species extends from Ceram, New Guinea, and the Solomons to the Marquesas and the Austral Islands, including Tonga, Fiji, and Samoa.

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## Upper Cretaceous Foraminifera from Japan

KIYOSHI ASANO<sup>1</sup>

IN THIS PAPER the discovery in Japan of smaller Foraminifera from the Upper Cretaceous strata is recorded for the first time. This contribution, in addition to its specific biostratigraphic application in Japan, has further interest by reason of its extension of the geographic range of the widely distributed Cretaceous pelagic foraminiferan, *Globotruncana*. In the north Pacific region, *Globotruncana* has heretofore been known only from the East Indian archipelago and from California.

This paper forms part of a project initiated by the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, for the purpose of assembling paleontologic data applicable to solution of stratigraphic problems connected with exploration for oil and coal in Japan. In the course of the geological survey connected with oil exploration in the Cretaceous areas of Hokkaido, Mr. S. Iijima of the Geological Survey of Japan collected samples in 1947 from the Upper Cretaceous rocks in the vicinity of Nakagawa-mura, Nakagawa-gun, Teshio district, Hokkaido, which, on examination, proved to contain a few specimens of *Globotruncana*. This identification was confirmed by Dr. Paul P. Goudkoff of Los Angeles, California, in a letter dated April 29, 1948. He identified *Globotruncana canaliculata* (Reuss) and species of *Gyroidina* and *Pleurostomella* in the sample. Subsequent study at Tohoku University of additional rock samples from the Upper Cretaceous of Hokkaido has revealed that although the occurrence of *Globotruncana* seems to be rare in the Absehinai

area of the Teshio district of Hokkaido, *Bathysiphon*, *Glomospira*, and *Ammodiscoides* are commonly found.

In a well which was drilled recently to test for coal seams at Yokouchi, about 2.5 km. south of Hisanohama-machi, Futaba-gun, Fukushima Prefecture (Lat. 37° 7' N, Long. 141° 00' E), on the island of Honshu, the assemblage described in this paper was discovered in cores from 187 to 215 meters. The presence of Upper Cretaceous rocks in this general area was already known from the work of Tokunaga and Shimizu (1926), who recorded *Trigonia*, *Inoceramus*, and ammonites, indicative of Senonian age. In the core samples, from the well at Yokouchi, which consist of carbonaceous sandstones and shales, *Trigonia*, *Inoceramus*, and fragments of ammonites were found from 70 to 215 meters.

The Foraminifera identified from the cores between 187 and 215 meters in the Yokouchi well are:

*Silicosigmoilina futabaensis*, n.sp.—dominant  
*Globotruncana canaliculata* (Reuss)—dominant

*Globotruncana marginata* (Reuss)—rare

*Globotruncana* sp.—rare

*Anomalina fukushimaensis*, n.sp.—dominant

*Trochammina hisanohamaensis*, n.sp.—few

*Robulus lepidus* (Reuss)—few

*Robulus futabaensis*, n.sp.—rare

*Robulus* sp.—few

*Marginulina cretacea* Cushman—rare

*Dentalina* cf. *basiplanata* Cushman—rare

*Dentalina* sp.—rare

*Vaginulina* cf. *lata* (Cornuel)—rare

*Palmula suturalis* (Cushman)—rare

*Ellipsonodosaria* sp.—rare

<sup>1</sup>Institute of Geology and Paleontology, Tohoku University, Sendai, Japan. Manuscript received September 7, 1949.



Both the dominant genera of this assemblage, *Globotruncana* and *Silicosigmoilina*, are recorded from Japan for the first time. Their range in Europe and North America is restricted to Upper Cretaceous formations. Several of the species recorded are widely distributed in the Upper Cretaceous strata of other regions, and four are described as new. *Silicosigmoilina futabaensis* occupies a position in the Japanese assemblage comparable to that of *S. californica* in the Upper Cretaceous of California. *Globotruncana canaliculata* is found in abundance in Europe and the Gulf Coast region of the United States, but more rarely in California.

The writer is indebted to Lt. Col. Hubert G. Schenck, chief of Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, and professor of geology at Stanford University, California, under whose supervision and encouragement the present investigation was conducted; to Mr. Leo W. Stach, head of the Petroleum Branch, Natural Resources Section, who was responsible for editing the manuscript; to the Hisanohama Coal Mining Co., which offered the core samples for study; to Dr. K. Hatai, Tohoku University, for advice and assistance during the investigation.

All specimens described herein are deposited in the collection of the Institute of Geology and Paleontology, Tohoku University, Sendai, Japan. Catalogue numbers of registered specimens are indicated in the text by the prefix IGPS.

#### Family SILICINIDAE

Genus *SILICOSIGMOILINA* Cushman and Church, 1929

*Silicosigmoilina futabaensis* Asano, n.sp.

Pl. 1, Figs. 6a, b; 7a, b

Test compressed, oval in side view, periphery subacute; chambers planispiral in earlier and sigmoidal in later stages; sutures indistinct, but fairly well marked between later

chambers, not deeply depressed; wall finely arenaceous, firmly cemented with siliceous cement; aperture simple, without a tooth; white or light gray in color. Length to 0.7 mm.; breadth 0.5–0.3 mm.; thickness 0.2–0.3 mm.

*Holotype*: IGPS 67016.

This species is related to *Silicosigmoilina californica* Cushman and Church, a species found abundantly in the Upper Cretaceous of California, but the Japanese species has a more compressed test.

#### Family TROCHAMMINIDAE

Genus *TROCHAMMINA* Parker and Jones, 1859

*Trochammina hisanohamaensis* Acano, n.sp.

Pl. 1, Figs. 8a–c

Test much compressed, planoconvex, dorsal side flat; ventral side slightly convex, umbilicate; chambers 4 or 5 in last coil, earlier chambers indistinct; sutures indistinct except for later ones which are somewhat depressed; wall finely arenaceous, smooth. Diameter to 0.6 mm.

*Holotype*: IGPS 67017.

*Trochammina texana* Cushman and Walters, from the Upper Cretaceous of the Gulf Coast region, is similar to this new species, but has less depressed sutures and the chambers have no raised borders.

#### Family LAGENIDAE

Genus *ROBULUS* Montfort, 1808

*Robulus futabaensis* Asano, n.sp.

Pl. 1, Figs. 12a, b

Test closely coiled, moderately compressed, periphery acute or with a slight keel; chambers distinct, of uniform shape and increasing gradually in size, 7 or 8 in adult coil; sutures distinct, gently curved, becoming thick and raised toward umbilical area; wall smooth;

aperture radiate with a weak slit ventrally. Diameter 1.2 mm.; thickness 0.4 mm.

*Holotype*: IGPS 67018.

This species differs from *Robulus williamsoni* (Reuss) in the presence of distinct raised sutures near the umbo.

***Robulus lepidus* (Reuss)**

Pl. 1, Fig. 13

*Robulus lepidus* Cushman and Church, 1929: 504, pl. 26, figs. 15, 16.

This species is said to be very common in the Upper Cretaceous rocks of Europe, California, and Mexico. The present specimens are identified with *Robulus lepidus* figured by Cushman and Church from the Upper Cretaceous of California.

***Robulus* sp.**

Pl. 1, Fig. 16

There are several incomplete specimens in the collection. The figured specimen has a distinct keel and an umbonate center, but

there is insufficient material for complete description.

**Genus MARGINULINA d'Orbigny, 1826**

***Marginulina cretacea* Cushman**

Pl. 1, Fig. 14

*Marginulina cretacea* Cushman, 1937: 94, pl. 13, figs. 12-15.

This species has been recorded from many localities in the Upper Cretaceous of the Gulf Coast region of the United States, but it is rare in the present collection.

**Genus DENTALINA d'Orbigny, 1826**

***Dentalina* cf. *basiplanata* Cushman**

Pl. 1, Fig. 11

*Dentalina basiplanata* Cushman, 1946: 68, pl. 24, figs. 1-6.

The apertural end is not preserved in any of the present specimens, although the limbate sutures are very characteristic as is shown in the figure. This species was originally described from the Corsicana Marl of Texas.

**EXPLANATION OF PLATE**

FIGS. 1a-c; 3a-c. *Globotruncana canaliculata* (Reuss).  $\times 40$ . a, Dorsal aspect; b, peripheral aspect; c, ventral aspect.

FIGS. 2a-c; 4a-c. *Globotruncana marginata* (Reuss).  $\times 40$ . a, Dorsal aspect; b, peripheral aspect; c, ventral aspect.

FIGS. 5a-c. *Globotruncana* sp.  $\times 45$ . a, Dorsal aspect; b, peripheral aspect; c, ventral aspect.

FIGS. 6a, b; 7a, b. *Silicosigmoilina futabaensis* Asano, n.sp.  $\times 40$ . a, Lateral aspect; b, apertural aspect. (Fig. 6, holotype. Fig. 7, paratype.)

FIGS. 8a-c. *Trochammina bisanohamaensis* Asano, n.sp.  $\times 40$ . a, Ventral aspect; b, peripheral aspect; c, dorsal aspect. (Holotype.)

FIG. 9. *Palmula suturalis* (Cushman).  $\times 35$ .

FIG. 10. *Dentalina* sp.  $\times 40$ .

FIG. 11. *Dentalina* cf. *basiplanata* Cushman.  $\times 40$ .

FIGS. 12a, b. *Robulus futabaensis* Asano, n.sp.  $\times 40$ . a, Lateral aspect; b, apertural aspect. (Holotype.)

FIG. 13. *Robulus lepidus* (Reuss).  $\times 40$ .

FIG. 14. *Marginulina cretacea* Cushman.  $\times 40$ .

FIG. 15. *Ellipsonodosaria* sp.  $\times 40$ .

FIG. 16. *Robulus* sp.  $\times 40$ .

FIGS. 17a, b; 18a-c. *Anomalina fukushimaensis* Asano, n.sp.  $\times 40$ . 17a, Dorsal aspect; b, ventral aspect. 18a, Ventral aspect; b, apertural aspect; c, dorsal aspect. (Fig. 17, paratype. Fig. 18, holotype.)

FIG. 19. *Vaginulina* cf. *lata* (Cornuel).  $\times 45$ .



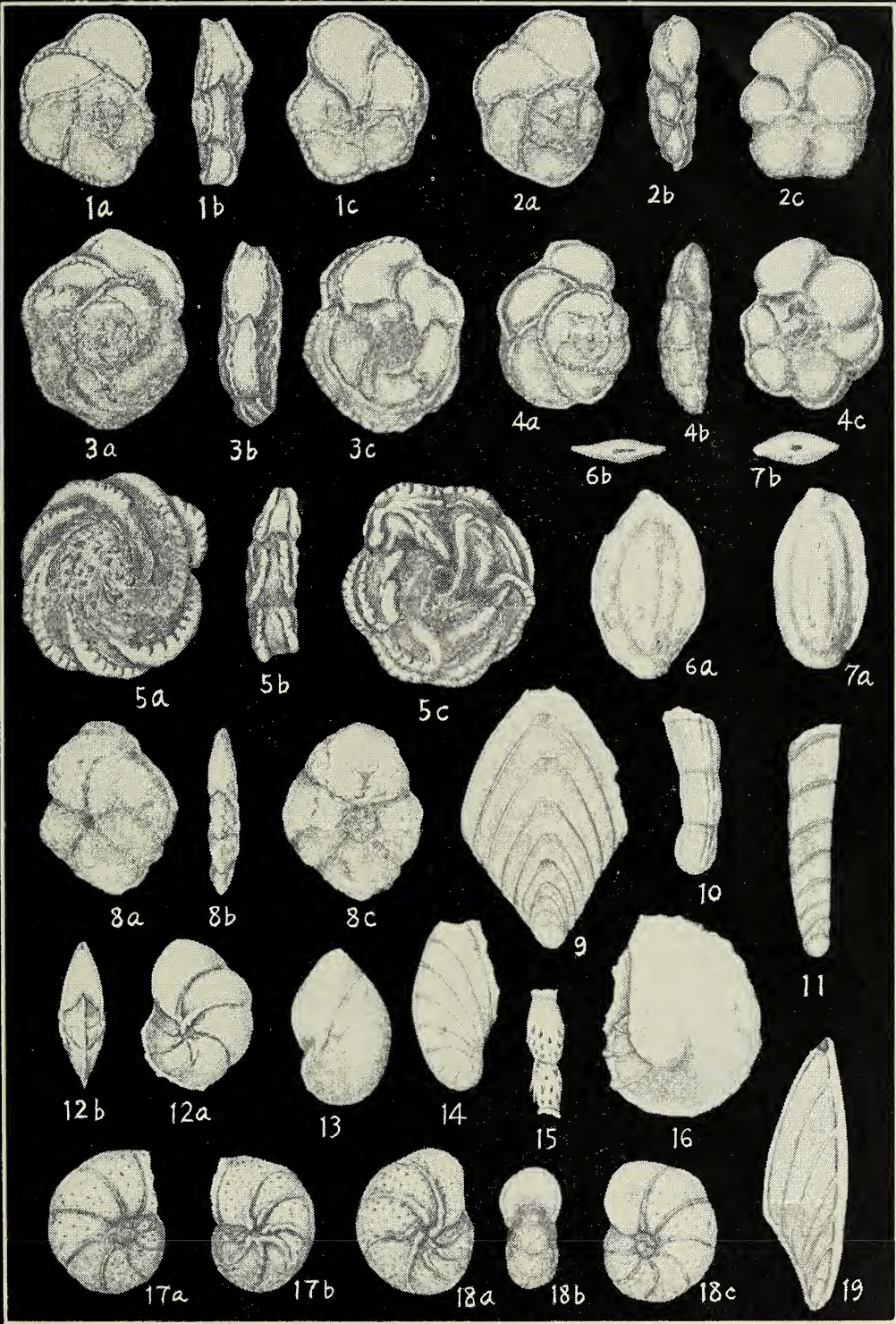


PLATE I  
Species of Foraminifera from the Upper Cretaceous strata of Japan.



**Dentalina** sp.

Pl. 1, Fig. 10

The single fragmentary specimen in the collection does not warrant description.

**Genus VAGINULINA** d'Orbigny, 1826**Vaginulina** cf. *lata* (Cornuel)

Pl. 1, Fig. 19

*Vaginulina lata* Cornuel, 1848: 252, pl. 1, figs. 34-37.

The single specimen figured is possibly the named species, but the inadequate material makes positive identification difficult.

**Genus PALMULA** Lea, 1833**Palmula** *suturalis* (Cushman)

Pl. 1, Fig. 9

*Flabellina suturalis* Cushman, 1935: 86, pl. 13, figs. 9-18.

*Palmula suturalis* Loetterle, 1937: 28, pl. 3, fig. 5.

The present specimens are very similar to those figured by both Cushman and Loetterle from the Upper Cretaceous of the Gulf Coast region of the United States.

**Family ELLIPSOIDINIDAE****Genus ELLIPSONODOSARIA** A. Silvestri, 1900**Ellipsonodosaria** sp.

Pl. 1, Fig. 15

The fragment of the spinose specimen figured resembles *Ellipsonodosaria horridens* Cushman, but the specimens are insufficient for specific identification.

**Family GLOBOROTALIIDAE****Genus GLOBOTRUNCANA** Cushman, 1927**Globotruncana** *canaliculata* (Reuss)

Pl. 1, Figs. 1a-c, 3a-c

*Globotruncana canaliculata* Cushman, 1946: 149, pl. 61, figs. 17, 18.

The present species is abundant and very characteristic of the Upper Cretaceous of Europe and America and is found commonly in the present collection. The type of this species is from the Senonian of Europe. There is considerable variation in the shape of the chambers. The nearly parallel faces and truncate periphery are characteristic features of this species. The present specimens are similar to the typical one figured by Cushman from Bavaria.

**Globotruncana** *marginata* (Reuss)

Pl. 1, Figs. 2a-c, 4a-c

*Globotruncana marginata* Cushman, 1946: 150, pl. 62, figs. 1, 2.

This species is found rarely in the present collection. The dorsal and ventral sides are difficult to distinguish from *G. canaliculata*, but the presence of a single keel or the tendency to have a truncate border in the later chambers of the peripheral side is a characteristic and distinguishing feature.

**Globotruncana** sp.

Pl. 1, Figs. 5a-c

This form differs from those described above in having strongly overlapped chambers with peculiar keels. Further material is needed for specific evaluation.

**Family ANOMALINIDAE****Genus ANOMALINA** d'Orbigny, 1826**Anomalina** *fukushimaensis* Asano, n.sp.

Pl. 1, Figs. 17a, b; 18a-c

Test planispiral, both sides convex, periphery broadly rounded; chambers distinct, 8 or 9 in last coil; sutures on dorsal side curved and limbate, but raised on ventral side, especially toward umbilical center; wall coarsely perforate except at umbilical region on ventral side; aperture an arched slit with a slight lip at base of last chamber. Diameter up to 0.5 mm.

*Holotype*: IGPS 67019.



This small species is similar to *Anomalina clementina* d'Orbigny in having raised ridges along the sutures, but is distinguished from that species by the more rounded periphery of the test.

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## News Notes

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, have been received. Each report includes a list of all the reports previously published.

*Reconnaissance Soil Survey of Japan (Kyu-*

*shu Area)*. [by Robert E. O'Brien and E. J. Kohler.] Report No. 110-B. 73 pp., 12 figs., 12 tables, 10 maps.

*Japanese Whaling Industry Prior to 1946*. [by William M. Terry.] Report No. 126. 47 pp., 17 figs., 19 tables.

## NOTES

### The Occurrence of a Black Marlin, *Tetrapterus mazara*, without Spear

Although it is quite commonly believed that the spearfishes are dependent upon the use of their spears as weapons for securing food, this is not necessarily the case as is demonstrated by the following observation:

A 545-pound black marlin (*Tetrapterus mazara* Jordan and Snyder), which was without a spear, was taken recently on long-line fishing gear, in Hawaiian waters. The specimen, with others of the same species, was brought into the auction room of the Kyodo Fishing Company, Ltd., on October 24, 1949. The appearance of the specimen indicated that the spear had been lost by injury. There was no indication that the loss was at all recent although considerable scar tissue was

present on the snout. Even though the fish was without a spear the specimen was equal in condition to the normal fish of the same species. This seems to disprove the belief that the spear is necessary for natural and adequate feeding. Unfortunately, length measurements of black marlin of this size are not practicable as the fish are cut in pieces to facilitate transporting to market.

According to the operators of the auction, spearfishes without spears have been observed before in the Honolulu market, although such occurrences are very rare.—Harvey L. Moore, Section of Biology and Oceanography, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, Hawaii.

### Additional Records Confirming the Trans-Pacific Distribution of the Pacific Saury, *Cololabis saira* (Brevoort)<sup>1</sup>

During January, 1948, the senior author and Dr. O. R. Smith of the U. S. Fish and Wildlife Service collected 10 specimens of *Cololabis saira* (Brevoort) by submerged light and dip net while aboard the tuna-fishing vessel "Oregon" en route from San Diego, California, to the Hawaiian Islands. One specimen 39.0 mm. long was taken on January 4 at 28° 22' N, 137° 12' W. Seven specimens, 30.0, 31.5, 33.0, 34.5, 34.5, 35.0, and 36.0 mm. in length, were captured on January 6 at 25° 14' N, 144° 41' W. One specimen 33.0 mm. long was taken on January 7 at 23° 52' N, 148° 41' W. A final

48.0 mm. specimen was captured on January 9 at 23° 04' N, 153° 19' W. All measurements are standard length.

These additional records of occurrence of the Pacific saury substantiate Hubbs's conclusion from morphological comparison that *C. saira* and *C. brevirostris* are not distinct species (Hubbs, *Univ. Calif. Pub. Zool.* 16 (3): 157, 1916), and Schultz's note (*Copeia*, 1940 (4):270), based on his collection of specimens in the oceanic areas between San Francisco and Honolulu, indicating that *C. saira* is trans-Pacific in distribution.—Milner B. Schaefer and John W. Reintjes, Section of Biology and Oceanography, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, Hawaii.

<sup>1</sup>Published by permission of the U. S. Fish and Wildlife Service.



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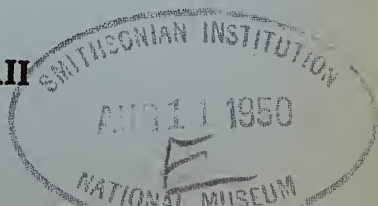
A QUARTERLY DEVOTED TO THE BIOLOGICAL  
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IN THIS ISSUE: Bushnell, Fukuda, and Makinodan—*Antibacterial Properties of Plants in Hawaii* • James—*Stratiomyidae from Okinawa and Guam* • Beveridge and Chapman—*Zonation of Marine Algae* • Atoda—“*Non-aquatic Frog*” of Palau • Papenfuss—*Identity of Spongocladia and Cladophoropsis* • Haneda—*Luminous Organs of Fish* • Leipper and Anderson—*Sea Temperatures* • Krauss—*Hawaiian Species of Carex* • NOTES

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Although no manuscript will be rejected merely because it does not conform to the style of PACIFIC SCIENCE, it is suggested that authors follow the style recommended below and exemplified in the journal.

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*Introduction and summary.* It is desirable to state  
{Continued on inside back cover}



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# The Antibacterial Properties of Some Plants Found in Hawaii

O. A. BUSHNELL, MITSUNO FUKUDA, AND TAKASHI MAKINODAN<sup>1</sup>

MANY OF THE PLANTS, both indigenous and introduced, which now grow in Hawaii have been used for medicinal purposes by the native Hawaiians and by the people of other countries who have come to live in Hawaii. When, in 1934, Handy, Pukui, and Livermore made their survey of the Hawaiian pharmacopeia, they were able to distinguish 317 different botanical components in the catalogue of ingredients used until that time. It is probable that many other species of plants which are sources of favorite remedies in other countries have been imported to Hawaii and could be added to the list prepared by Handy and his coworkers (1934), who were concerned primarily with remedies used by the native Hawaiians.

The Hawaiian remedies, especially those derived from the lore of the *kahuna lapaan laan*, the herb doctor of the ancient Hawaiians, have been much praised but they have never been critically appraised; and we thought that perhaps we could gain some idea of their relative value if we studied the medicinal plants from which these remedies were prepared for evidences of the antibacterial properties they might possess.

Most of the plants we set out to study were chosen from the native Hawaiian *materia medica*, but we did not exclude plants used for medicinal purposes by people of other ethnic groups. In some instances, moreover, we studied imported plants which were related to the species considered to be of value by the Hawaiians, even though the imported

plants were not themselves mentioned in the accounts we consulted in preparing our own list of plants to be investigated.

Our list was compiled from several publications discussing Hawaiian pharmaceuticals (Kaaikamanu and Akina, 1922; Degener, 1930; Handy, Pukui, and Livermore, 1934; Neal, 1948); from suggestions given us by a Hawaiian herbalist on plants in current usage; and from hearsay and our own personal experience with plants used by Japanese, Chinese, and other ethnic groups in Hawaii. In preparing this list, those plants which appear to have been used against bacterial infections were selected wherever identification of the plant had been established and whenever it was likely that we would be able to find it in order to test it. The more common or the more famous of the medicinal plants were also included in the list, even if they had been employed to treat conditions obviously having no bacterial etiology. Our list, then, is a heterogeneous one, by no means confined to the native Hawaiian plants, and contains more than 275 entries.

When we began these studies we expected to be able, in time, to study all the plants in our list, and therefore were not particularly concerned about the order in which we collected them, taking them in the haphazard sequence in which we found them; but now the pressure of other duties makes it evident that we shall not be able to finish the studies as we had planned. Rather than lose the information we have obtained, therefore, we are recording in this paper the data from our observations on the 101 medicinal plants we were able to investigate before our studies were forced to an end.

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<sup>1</sup>Department of Bacteriology, University of Hawaii, Honolulu. Manuscript received August 29, 1949.

## METHODS

The method of measuring the antibacterial properties of plants is essentially the same as that devised by the Oxford group (Abraham *et al.*, 1941) for assaying penicillin and since adapted to the assay of other antibiotics produced by micro-organisms. It is a method which has been used in other parts of the world to appraise medicinal plants (Pederson and Fisher, 1944; Lucas and Lewis, 1944; Sanders, Weatherwax, and McClung, 1945; Carlson *et al.*, 1946; and many others). It is based upon the assumption that an agent which acts upon a test organism to achieve a particular effect will also act upon other related organisms in a similar manner. While the assumption is not always substantiated by experimental evidence, it is tenable often enough to give the method some usefulness as a "screening test" for distinguishing agents that are "likely" to be effective from those which are "likely" to be ineffective. It is a method which has its deficiencies, certainly, but it is better than no method at all.

The plants to be studied were collected over a period of 2 years as they could be found on the island of Oahu. Most of them were obtained on or near the University of Hawaii campus and in the adjacent Manoa Valley. Whenever feasible, specimens of the complete plant—roots, stems, leaves, buds, flowers, and fruits—were obtained, either all at once or during those seasons when they could be found. In the case of a plant of which only certain portions had been used in the native pharmacopeia, we were careful to collect and to study at least those prescribed portions of the plant if not all of it. Many of the plants, or many of the parts of the different species, were tested several times during the course of our study, in several instances by each of us independently.

The specimens were taken to the laboratory soon after they were collected, and either were subjected immediately to the process of

assay or were frozen and held at  $-10^{\circ}$  C. until they could be studied.

Extracts of the whole plants or of certain separated portions of them—as, for example, the roots, the stems, the leaves, the flowers, the fruits, or of any indicated combinations of these—were obtained by first cutting the plant material into small pieces and by then subjecting these fragments to high pressures, ranging from 15,000 to 20,000 pounds per square inch, achieved by means of a Carver hydraulic press. No water or solvent of any kind was added to the plant material, and in almost all cases the specimens yielded ample amounts of tissue fluids for the purposes of the study.

The extracts of the different portions of the plants were kept in separate beakers, and were placed immediately in a refrigerator until the next step in the assay could be performed. In most instances the period of storage was only 1 to 2 hours; in no case was it longer than 4 hours.

Most of the extracts were assayed for their antibacterial effect upon three test strains of bacteria: *Micrococcus pyogenes* var. *aureus* (until recently known as *Staphylococcus aureus*), *Escherichia coli*, and *Pseudomonas aeruginosa*. A few of those extracts studied early in these investigations were tested against *M. pyogenes* var. *aureus* and *E. coli* only. Seventeen of the plants, which the literature described as having been employed to combat intestinal infections, were tested against five different strains of enteric pathogens as well as against the three standard cultures. The enteric pathogens used were: *Salmonella typhosa*, *Sal. montevideo*, *Sal. schottmuelleri*, *Shigella paradysenteriae* BH, and *Shig. paradysenteriae* III-Z. Cultures of all of these test organisms were obtained from the stock culture collection of the Department of Bacteriology, University of Hawaii.

Pure cultures of the test bacteria were grown in nutrient broth at  $37^{\circ}$  C. for 24 hours before they were used. When an assay



was about to be performed, 0.5 ml. of the broth culture of the test organism was inoculated into 100 ml. of melted nutrient agar cooled to 41° C. This heavily seeded agar medium was then poured into sterile petri dishes, about 10 ml. to a dish, and the medium was allowed to solidify at room temperature. After the medium had solidified, one or two sterile porcelain penicups were placed upon the surface of the agar.

The plant extract being tested was then placed in the appropriate penicup, 0.2 ml. of extract in each cylinder. At first extracts were tested in duplicate until, with time and the perfection of our techniques, we found that duplicate platings were unnecessary. The plates were incubated in the upright position at 37.5° C. for 24 hours, at which time they were examined for the degree of inhibition achieved by the plant extracts as they diffused into the medium from the bases of the penicups. In most of the instances in which inhibition was achieved, it was denoted by a clear halo-like zone in the medium around the penicup, with the heavy growth of uninhibited bacteria making the medium opaque around the periphery of the zone of inhibition. A few of the plant extracts produced a considerable discoloration or opacity in the medium around the penicups, but in only a very few instances did this discoloration interfere with determinations of the extracts' effects upon the test organisms.

The degree of antibacterial effect was reflected directly, of course, in the size of the zone of inhibition: the greater the zone, the more potent the extract. The diameter of the zone could be measured quite easily in most instances and was recorded, in millimeters, for each extract tested.

Several other techniques for determining the efficacy of the plant extracts were also tried—such as using filter paper discs of varying sizes soaked in the plant extract before they were applied to the inoculated agar, or actually incorporating 1 ml. of the plant ex-

tract or of varying dilutions of it into the inoculated medium before it had solidified—but the penicup method seemed to be the one which gave the most consistent and the most clear-cut results, and it was adopted for continued use.

Just before each extract was tested for its effect upon the bacteria, its pH was determined by means of a Macbeth line-operated pH meter. A series of tests was also performed to determine the inhibitory effect of H-ions and OH-ions in buffer solutions of assorted pH in order to ascertain whether or not the inhibitory effects of the different plant extracts might be merely a reflection of their pH values. The buffer solutions were prepared from tablets each of which, upon being dissolved in 100 ml. of distilled water, gave a solution of specified pH value.<sup>2</sup>

Information concerning the plants reported in this paper is presented in Table 1, which shows (1) the major plant group and the family to which each plant belongs; (2) the scientific name of the plant; (3) the common names of the plant, in both English and Hawaiian; and (4) epitomes of the usual purposes for which the plant was employed, according to the references consulted in preparing the list (the specific references are cited in the table).

We can make no claim to being taxonomists and have based our presentation of the systematic relationships of these plants upon the manner in which Neal has set them forth in her recent book *In Gardens of Hawaii* (1948). In her introduction to this compendium, Miss Neal states that she has followed the system of Engler and Prantl for the flowering plants, and the arrangement of A. J. Eames for the ferns and fern allies.

The single specimen of alga collected, *Gracilaria furcellata*, was identified by Dr. Marion L. Lohman, associate professor of botany at the University of Hawaii. Most of the

<sup>2</sup>The tablets are produced by the Coleman Electric Company, Maywood, Ill.

TABLE 1

SCIENTIFIC AND COMMON NAMES OF THE PLANTS TESTED, THEIR SYSTEMATIC RELATIONSHIPS, AND THE MEDICINAL USES TO WHICH THEY WERE PUT

(K & A = Kaaikamanu and Akina, 1922; Deg. = Degener, 1930; Handy = Handy, Pukui, and Livermore, 1934; Neal = Neal, 1948)

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Gracilariaceae	<i>Gracilaria furcellata</i> Mont.	seaweed; <i>l'imu manaua</i> (?)	sores, skin blotches, "cure for miscarriage" (K & A: 62)
Psilotaceae	<i>Psilotum nudum</i> (L.) Griseb.	upright <i>Psilotum</i> ; <i>moa</i>	thrush, diarrhoea in infants (Deg.: 20; Neal: 7)
Gleicheniaceae	<i>Dicranopteris linearis</i> (Burm.) Underw.	false staghorn fern; <i>uluhe</i>	laxative (Deg.: 27)
Polypodiaceae	<i>Nephrolepis biserrata</i> (Sw.) Schott.	related to Boston fern; <i>okupukupu</i>	not known (listed in Handy: 44)
	<i>Cibotium Chamissoi</i> Kaulf.	tree fern; <i>hapu</i>	asthma, "lung troubles" (K&A: 16)
Pandanaceae	<i>Freycinetia arborea</i> Gaud.	climbing screwpine; <i>ieie</i>	general debility, thrush, high fever (K & A: 22)
	<i>Pandanus Rockii</i> Mart.	a screwpine, related to the <i>bala</i> of the Hawaiians	<i>bala</i> was used for general debility, constipation, "pain in chest" (K & A: 41); asthma (personal communication)
Gramineae	<i>Bambusa</i> sp.	"small-leaved bamboo"; <i>obe laulii</i>	ulcers and scrofulous sores (K & A: 30)
	<i>Coix lacryma-jobi</i> L.	Job's tears; <i>pu oheohe</i>	curative charm (Neal: 74)
	<i>Saccharum officinarum</i> L.	sugar cane; <i>ko kea</i>	cuts and wounds, urethritis (K & A: 6, 53); adjuvant (Handy: 21); pulmonary disease (personal communication)
	<i>Setaria palmifolia</i> (Willd.) Stapf	palm grass	use unknown; hearsay
	<i>Stenotaphrum secundatum</i> (Walt.) Ktze.	buffa'o grass; <i>akiaki</i> , <i>manienie mahikihiki</i>	sores and ulcers on skin (K & A: 10)
Cyperaceae	<i>Scirpus validus</i> Vahl.	great bulrush; <i>aka'akai</i> , <i>naku</i> , <i>neki</i>	"gripping pain of the stomach or intestines, and for intestinal hemorrhages" (K & A: 10)
Palmae	<i>Cocos nucifera</i> L.	coconut; <i>niu</i>	general debility and cuts (K & A: 73); thrush (Handy: 22)
Araceae	<i>Alocasia macrorrhiza</i> (L.) Sweet	<i>ape keokeo</i>	burns, stomach ache, aphrodisiac (K & A: 17)
	<i>Colocasia esculenta</i> (L.) Schott.	taro; <i>kalo</i>	laxative (K & A: 17)
Commelinaceae	<i>Commelina diffusa</i> Burm. f.	day flower; <i>honobono</i> , <i>makolokolo</i>	"purifying the blood" (K & A: 71)
Liliaceae	<i>Allium fistulosum</i> L.	green onion; <i>aka'akai</i>	tuberculosis, colds, and venereal diseases (K & A: 10)
	<i>Cordyline terminalis</i> (L.) Kunth. var <i>Ki</i> (Schott.) J. G. Baker	<i>ti</i> , <i>ki</i> , <i>lau'i</i>	asthma, congestion of lungs, high fever (K & A: 50)
Dioscoreaceae	<i>Dioscorea alata</i> L.	yam; <i>uhi</i>	high fever (K & A: 37)
Musaceae	<i>Musa paradisiaca</i> L. ssp. <i>sapientum</i> (L.) Ktze. var.	banana; <i>mai'a</i>	asthma, general debility, stomach disorders (K & A: 65-68); throat infection (personal communication)



TABLE 1 (Continued)

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Zingiberaceae	<i>Alpinia purpurata</i> (Vieill.) K. Schum.	red ginger	use unknown; hearsay
	<i>Hedychium coronarium</i> Koenig	white ginger; <i>awapuhi</i> <i>keokeo</i>	"for foetid nostrils" (K & A: 20)
	<i>Zingiber Zerumbet</i> (L.) Smith	mountain ginger; <i>awapuhi kuabiwi</i>	cuts and sores (K & A: 19)
Casuarinaceae	<i>Casuarina equisetifolia</i> L.	ironwood	astringent (Neal: 247)
Piperaceae	<i>Peperomia membranacea</i> H. & A.	peperomia; <i>alaalawainui</i>	general debility, pulmonary dis- eases, venereal diseases, scro- fulous swellings and ulcers (K & A: 13-14)
Moraceae	<i>Peperomia latifolia</i> Miq.	peperomia; <i>alaalawainui</i>	same as above
	<i>Artocarpus incisus</i> (Thunb.) L. f.	breadfruit; <i>ulu</i>	skin diseases and boils (K & A: 38; Handy: 31)
	<i>Morus alba</i> L., f. <i>nigrobacca</i> Mold.	mulberry; <i>kilika</i>	use unknown; hearsay
Urticaceae	<i>Touchardia latifolia</i> Gaud.	<i>olona</i> , <i>wanke-malulo</i>	"bodily ailments or weaknesses" (K & A: 71)
Santalaceae	<i>Santalum album</i> L.	Indian sandalwood; re- lated to the <i>iliabi</i> of the Hawaiians	<i>iliabi</i> was used for sores, vene- real diseases (K & A: 24; Neal: 278)
Amaranthaceae	<i>Amaranthus spinosus</i> L.	spiny amaranth; <i>pokai</i> <i>kuku</i>	use unknown; hearsay
Nyctaginaceae	<i>Mirabilis Jalapa</i> L.	four o'clock; <i>nani abiabi</i>	poultices, purgatives (Neal: 288)
Batidaceae	<i>Batis maritima</i> L.	pickleweed; <i>akulikuli</i> <i>kai</i>	"leaves have medicinal value" (Neal: 291)
Portulacaceae	<i>Portulaca oleracea</i> L.	pigweed; <i>akulikuli kula</i> , <i>ibi-ai</i> , <i>lumaba'i</i>	general debility (K & A: 24)
Cruciferae	<i>Nasturtium officinale</i> R. Br.	water cress; <i>leko</i>	"for dry throat and cold in the head," asthma (K & A: 64); tuberculosis (personal com- munication)
Crassulaceae	<i>Bryophyllum pinnatum</i> (Lam.) Kurz.	air-plant	fevers (Neal: 329)
Pittosporaceae	<i>Pittosporum Tobira</i> (Thunb.) Ait.	related to the <i>ho'awa</i> of the Hawaiians	<i>ho'awa</i> was used for sores (Neal: 335); scrofula (K & A: 44)
Rosaceae	<i>Rubus rosaefolius</i> Sm.	thimbleberry	use unknown; hearsay
Leguminosae	<i>Acacia confusa</i> Merr.	Formosa koa	use unknown; chosen for its re- lationship to <i>Acacia Koa</i>
	<i>Acacia Koa</i> Gray	<i>koa</i> , <i>kabilikolo</i>	general debility, diseases of the skin (K & A: 46)
	<i>Cassia Leschenaultiana</i> DC.	cassia; <i>lauki</i>	use unknown; hearsay
	<i>Crotalaria incana</i> L.	rattlebox; <i>pikakani</i>	use unknown (listed in Handy: 74)
	<i>Crotalaria mucronata</i> Desv.	rattlebox; <i>pikakani</i>	use unknown; hearsay
	<i>Dioclea violacea</i> Mart.	sea bean; <i>maunaloa</i>	cuts, skin diseases, "purifying the blood" (K & A: 65)
	<i>Leucaena glauca</i> (L.) Benth.	false koa; <i>koa haole</i>	use unknown; hearsay
	<i>Medicago sativa</i> L.	alfalfa	use unknown; hearsay
	<i>Prosopis chilensis</i> (Mol.) Stuntz	algaroba; <i>keawe</i>	dysentery, sore throat (Neal: 363)

TABLE 1 (Continued)

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Rutaceae	<i>Tamarindus indica</i> L.	tamarind; <i>wi 'awa 'awa</i>	"used medicinally in India" (Neal: 366)
	<i>Vigna marina</i> (Burm.) Merr.	<i>nanea, okoleomakili</i>	general debility, asthma, boils and cuts (K & A: 33)
	<i>Citrus aurantifolia</i> (Christmann) Swingle	lime	use unknown; hearsay
	<i>Pelea</i> sp.	<i>alani</i>	general debility, "purifying the blood," skin diseases: "makes the skin immune to certain diseases" (K & A: 16)
Euphorbiaceae	<i>Aleurites moluccana</i> (L.) Willd.	candlenut tree; <i>kukui</i>	general debility, asthma, scrofulous sores, ulcers of skin (K & A: 56-57); diphtheria (personal communication)
	<i>Euphorbia hirta</i> L.	hairy spurge; <i>kokokabiki, akoko</i>	cathartic, gargle, poultice (Handy: 19); thrush (Deg.: 198)
	<i>Euphorbia pulcherrima</i> Willd.	poinsettia; <i>koko</i>	use unknown (listed in Handy: 39, 44)
	<i>Euphorbia Milii</i> Ch. des Moulins	crown-of-thorns	use unknown; hearsay
	<i>Euphorbia Tirucalli</i> L.	pencil plant	use unknown; hearsay
	<i>Hura crepitans</i> L.	sand-box tree	"leprosy and other conditions" (Neal: 451)
Anacardiaceae	<i>Ricinus communis</i> L.	castor bean; <i>koli, pa'aila</i>	fever (K & A: 55)
	<i>Mangifera indica</i> L.	mango; <i>manako</i>	astringent (Neal: 457)
	<i>Schinus terebinthifolius</i> Raddi	Christmas berry tree; <i>wilelaiki</i>	use unknown; hearsay
Sapindaceae	<i>Cardiospermum</i>	balloon vine, heartseed;	rheumatism, digestive and pulmonary disorders (Neal: 467)
	<i>Halicacabum</i> L.	<i>inalua, poniu</i>	
Malvaceae	<i>Dodonaea viscosa</i> L.	<i>aalii, kumakani</i>	rash and itch (K & A: 2)
	<i>Hibiscus tiliaceus</i> L.	<i>bau kae kae</i>	laxative (Neal: 49); congested chest, sore throat (K & A: 40)
	<i>Malvastrum coromandelianum</i> (L.) Garcke	false mallow	poultices (Neal: 485)
	<i>Sida fallax</i> Walp.	<i>ilima</i>	general debility, asthma, "fallen womb," laxative (K & A: 26; Neal: 485)
Sterculiaceae	<i>Waltheria americana</i> L.	<i>hialoa, uhaloa, kanakalao</i>	asthma, sore throat, pulmonary complications (K & A: 37; Neal: 503; personal communication)
Guttiferae	<i>Calophyllum</i>	Alexandrian laurel;	use unknown (listed in Handy: 43; Neal: 513)
Passifloraceae	<i>Inophyllum</i> L.	true <i>kamani</i>	
	<i>Passiflora edulis</i> Sims f. <i>flavicarpa</i> Degener	yellow <i>lilikoi</i>	use unknown; hearsay
Caricaceae	<i>Passiflora foetida</i> L. var.	running pop, red passion fruit	use unknown; hearsay
	<i>Passiflora</i> sp.	green <i>lilikoi</i>	use unknown; hearsay
	<i>Carica Papaya</i> L.	papaya; <i>nikana, he'i</i>	skin diseases (Neal: 527); deep cuts (K & A: 43)
Cactaceae	<i>Opuntia megacantha</i> Salm-Dyck	prickly pear; <i>panini</i>	constipation (K & A: 73)



TABLE 1 (Continued)

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Thymeliaceae	<i>Wikstroemia oahuensis</i> (Gray) Rock	<i>akia</i>	laxative, asthma (K & A: 8); fish poison (Neal: 540; Deg.: 224-225)
Punicaceae	<i>Punica Granatum</i> L.	pomegranate; <i>pomaikalana</i>	used in Orient (Neal: 551)
Combretaceae	<i>Terminalia Catappa</i> L.	tropical almond; false <i>kamani</i>	"used medicinally" (Neal: 551)
Myrtaceae	<i>Eucalyptus</i> sp.	eucalyptus; <i>nubolani</i>	fevers, sores, pains, rheumatism (K & A: 73)
	<i>Eugenia Cumini</i> (L.) Druce	Java plum	use unknown; hearsay
	<i>Eugenia malaccensis</i> L.	mountain apple; <i>obia ai</i>	general debility, thrush, sores, cuts (K & A: 31-32); throat infection (personal communication)
	<i>Metrosideros macrophus</i> H. & A.	<i>obia lehua</i> , <i>obia hamanu</i>	sore throat, bronchitis, consumption, wounds (Handy: 20)
	<i>Psidium Guajava</i> L.	guava; <i>kuawa</i>	"medicinal tea" (Neal: 556); deep cuts, sprains, diarrhoea, intestinal hemorrhages (K & A: 55)
Apocynaceae	<i>Nerium Oleander</i> L.	oleander; <i>oleana</i>	skin diseases (Neal: 611)
	<i>Thevetia peruviana</i> (Pers.) K. Schum.	be-still, yellow oleander	"used medicinally" (Neal: 610)
Convolvulaceae	<i>Ipomoea Batatas</i> (L.) Poir.	sweet potato; <i>uala</i>	medicinal uses (Handy: 21); asthma, constipation, "fallen womb" (K & A: 35-36)
	<i>Ipomoea congesta</i> R. Br.	morning glory; <i>koali awabia</i>	purgative, healing broken bones (Handy: 19; K & A: 52; Neal: 623); relief of muscular pain (personal communication)
	<i>Ipomoea pes-caprae</i> (L.) Sweet	beach morning glory; <i>pohuehue</i>	"good for the expectant mother" (K & A: 73)
Boraginaceae	<i>Messerschmidia argentea</i> (L. f.) Johnston	tree heliotrope; <i>tabinu</i>	use unknown; hearsay
Verbenaceae	<i>Lantana Camara</i> L.	lantana; <i>lakana</i>	use unknown; hearsay
	<i>Stachytarpheta cayennensis</i> (L. C. Rich.) Vahl.	vervain; <i>oi</i>	"used in tropical America" (Neal: 639)
Solanaceae	<i>Capsicum frutescens</i> L.	red pepper; <i>nioi</i>	pains in back, rheumatism, swollen feet (K & A: 72)
	<i>Lycopersicon esculentum</i> Mill. ssp. <i>Galenii</i> (Mill.) Luckwill	currant tomato; <i>obia makanabele</i>	use unknown; hearsay
	<i>Solanum nodiflorum</i> Jacq.	black nightshade; <i>popolo</i>	disorders of respiratory tract, skin eruptions, cuts, wounds (Handy: 18; Neal: 655); trachoma (personal communication)
	<i>Solanum sodomaeum</i> L.	apple of Sodom; <i>popolo kikania</i>	used in Africa for skin diseases (Neal: 655)

TABLE 1 (Continued)

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Plantaginaceae	<i>Plantago lanceolata</i> L.	narrow-leaved plantain; <i>laukahi</i>	sores or boils (Handy: 21); general debility, constipation, boils (K & A: 58); diabetes and "to clear the system" (Neal: 695)
	<i>Plantago major</i> L.	broad-leaved plantain; <i>laukahi</i>	same as above
Rubiaceae	<i>Morinda citrifolia</i> L.	Indian mulberry; <i>noni</i>	broken bones, deep cuts (K & A: 73); cuts, bruises, sores, wounds (Handy: 18)
Cucurbitaceae	<i>Momordica Charantia</i> L.	bitter melon, balsam pear	used in the preparation of a Japanese remedy for skin ail- ments, headache, constipation (Neal: 709)
Goodeniaceae	<i>Scaevola frutescens</i> (Mill.) Krause var. <i>sericea</i> (Forst. f.) Merr.	beach naupaka; <i>naupaka</i> <i>kabakai</i>	"used medicinally in Malaya" (Neal: 720); cuts and skin diseases (K & A: 72)
	<i>Scaevola Gaudichau- diana</i> Cham.	mountain naupaka; <i>naupaka kuahiwi</i>	same as above
Compositae	<i>Bidens pilosa</i> L.	beggar tick; related to the <i>ko'oko'olau</i> of the Hawaiians	"used medicinally" (Neal: 742)
	<i>Erigeron albidus</i> (Willd.) Gray	related to Canada flea- bane; <i>iliobe</i>	"used medicinally in Java" (Neal: 733; listed in Handy: 42)

plants were identified for us by Dr. Harold St. John, professor of botany and chairman of the Department of Botany at the University of Hawaii. We are grateful for their help and their encouraging interest in these studies. At Dr. St. John's suggestion, herbarium specimens of the plants studied were prepared by us and are preserved in the Department of Bacteriology at the University of Hawaii.

#### DATA AND DISCUSSION

We are well aware of the shortcomings of this approach to an appraisal of the medicinal plants found in Hawaii, if only because so many of these plants were not used primarily for their effect against bacteria: they were used as cathartics, vermifuges, emollients, astringents, analgesics, counterirritants, and other salutaries, as well as for their action in preventing infection and for treating an in-

fection once it had begun. We know, too, that studying the effects of these plants upon bacteria *in vitro* does not test them under the conditions *in vivo* in which they were intended to be used: there are so many factors involved in the living body which might contribute important assistance to the medicinal agent when it is properly applied by the herbalist. The purists among admirers of the *kabuna's* lore will also point out that we did not use the ancient prescriptions exactly as they were applied by the *kabuna*. To this our answer must be that, in this initial stage of the investigation, we were concerned with studying the effects of the component parts of the prescriptions, hoping that later, when we had found all of the components, we could put them together to see if they are any more effective when they are used concurrently than when they are used alone.

The number of kinds of plants available



for study was limited, too. Many of those which played an important part in the *kabuna's* pharmacy were difficult to obtain even in their day, and are even harder to find now. Some of them have become extinct or inaccessible, and most of the plants grow in habitats so far removed from the laboratory that they are not conveniently available for study.

The number of species of bacteria we could use to determine the "spectrum" of activity of a plant—that is, the range of its effectiveness as an antagonistic agent for the different species of bacteria— was so limited by the time and facilities at our disposition that we could not possibly expose all of the different micro-organisms which might have assailed a susceptible Hawaiian.

Nonetheless, the determination of the antibacterial effect of extracts of the different medicinal plants offers the one feasible means for assaying them in the absence of human cases to study or of laboratory animals to experiment upon.

Before very many plants were tested it became evident that there were great variations in effectiveness of the plant extracts obtained from the different species of plants, and, indeed, often among extracts obtained from the several parts of the same plant. There was also considerable variation in effectiveness of many of the extracts against the several different test organisms.

It is difficult, then, to tabulate easily the results obtained in this study. We have finally decided to do what the Hawaiians did, and to treat each separate part of a plant as an entity of its own—if only because we found, as they did, that the different parts of the plant vary astonishingly in their pharmacological properties.

We set some arbitrary standards of efficacy, basing these standards upon the Oxford group's definition of a unit of penicillin—that amount of penicillin which gives an inhibition zone 24 mm. in diameter—and the work of Sanders *et al.* (1945) in appraising the antibacterial substances in plants collected in Indiana. Four categories were established, based upon the diameters of the zones of inhibition obtained with the plant extracts *against any one of the test organisms*:

1. Very effective: zones more than 20 mm. in diameter
2. Moderately effective: zones between 10 and 20 mm. in diameter
3. Slightly effective: zones less than 10 mm. in diameter
4. Ineffective: no apparent zone of inhibition

The summarized data of our studies are presented in Tables 2–6 and in a simple listing of the ineffective extracts (see p. 179). Table 2 presents the results of the studies with buffer solutions of different pH values. Tables

TABLE 2

EFFECT OF BUFFER SOLUTIONS OF DIFFERENT pH UPON THE TEST BACTERIA

TEST ORGANISMS	ZONES OF INHIBITION (IN MM.) ACHIEVED BY 0.2 ML. OF BUFFER SOLUTIONS		
	pH 3.0	pH 4.0	pH 5.0, 6.0, 8.0
<i>Micrococcus pyogenes</i> var. <i>aureus</i> . . . . .	10	0	0
<i>Escherichia coli</i> . . . . .	10	8	0
<i>Pseudomonas aeruginosa</i> . . . . .	12	8	0
<i>Salmonella typhosa</i> . . . . .	8	0	0
<i>Salmonella montevideo</i> . . . . .	10	0	0
<i>Salmonella schottmuelleri</i> . . . . .	12	8	0
<i>Shigella paradysenteriae</i> BH . . . . .	13	0	0
<i>Shigella paradysenteriae</i> III-Z . . . . .	13	0	0

3-6 are concerned with the antibacterial effects of the plant extracts and present this information: (1) the scientific name of the plant; (2) the part of the plant yielding the extract being tested; (3) the pH of the extract; and (4) the diameters of the zones of inhibition, measured in millimeters, developed against the different test organisms. Wherever, by intention or by accident, a particular bit of information was not obtained, a question mark (?) indicates this fact; the words "not tested" mean that the organism (usually *Ps. aeruginosa*) was not used in the testing of a particular extract; the symbol "qns" means "quantity not sufficient" to obtain a pH determination; the symbol "O" means no apparent zone of inhibition.

The tests showed that very acid buffer solutions (pH 3.0 and 4.0) are only moderately effective in their ability to inhibit growth of the test organisms, and that solutions with pH values ranging from 5.0 to 8.0 had no effect at all.

This is an observation that has direct bearing upon the results disclosed in this study of extracts from Hawaiian medicinal plants, for, in a number of instances—as will be seen from Tables 3 to 6—it was found that the zones of inhibition produced by the extracts were far greater than were the zones of inhibition produced by the buffer solutions having the same pH values as did the extracts being tested. In those extracts having a pH more acid than 3.0, moreover, the degree of inhibition achieved by the extracts was significantly greater than that achieved by the buffer solution of pH 3.0. On the other hand, as the list on page 179 shows, there were also many extracts of moderate acidity which exerted no inhibitory effect at all upon the test bacteria.

The implication here is that, in those plant extracts which are potent in their degree of inhibition of the test bacteria, it is not so much the mere pH of the extract that is the effective antibacterial agent, but rather the

TABLE 3  
EXTRACTS WHICH EXHIBIT VERY EFFECTIVE ANTIBACTERIAL PROPERTIES  
(with zone of inhibition 20 mm. or more in diameter)

NAME OF PLANT	PART OF PLANT PROVIDING EXTRACT	pH OF EXTRACT	DIAMETER OF ZONES OF INHIBITION (IN MM.)		
			<i>M. pyogenes</i>	<i>E. coli</i>	<i>Ps. aeruginosa</i>
<i>Dicranopteris linearis</i>	leaves and stems	4.6	21	0	13
<i>Alpinia purpurata</i>	leaves	6.6	10	22	20
<i>Acacia Koa</i>	stems	5.6	20	0	0
<i>Tamarindus indica</i>	ripe fruit	2.4	30	30	not tested
	fruit, aqueous extract	?	25	24	not tested
	green fruit	2.5	25	26	25
<i>Citrus aurantifolia</i>	fruit	2.6	27	25	25
<i>Hura crepitans</i>	flowers	4.5	20	14	(discolored)
<i>Passiflora edulis</i> f. <i>flavicarpa</i>	green fruit	3.4	27	28	30
	ripe fruit	3.7	22	22	20
<i>Passiflora foetida</i> var.	fruit	4.2	15	32	15
<i>Passiflora</i> sp.	flowers	5.6	10	35	10
<i>Punica Granatum</i>	whole fruit*	3.5	20	20	15
	fruit-rind	3.7	22	0	13
<i>Eugenia malaccensis</i>	seeds	4.7	25	0	0
	bark*	5.9	20	0	not tested
	leaves*	5.4	20	0	not tested
<i>Metrosideros macropus</i>	stems	4.9	30	8	8
<i>Psidium Guajava</i>	leaves and flowers	?	20	10	not tested

\* See Table 6.



TABLE 4  
EXTRACTS WHICH EXHIBIT MODERATELY EFFECTIVE ANTIBACTERIAL PROPERTIES  
(with zones of inhibition between 10 and 20 mm. in diameter)

NAME OF PLANT	PART OF PLANT PROVIDING EXTRACT	pH OF EXTRACT	DIAMETER OF ZONES OF INHIBITION (IN MM.)		
			<i>M. pyogenes</i>	<i>E. coli</i>	<i>Ps. aeruginosa</i>
<i>Psilotum nudum</i>	whole plant	5.2	15	0	8
<i>Nephrolepis biserrata</i>	stems	5.1	12	0	0
<i>Cibotium Chamissoi</i>	leaflets	4.6	14	15	12
	buds (of leaves)	5.2	10	0	8
<i>Freycinetia arborea</i>	stems	5.8	11	0	0
<i>Allium fistulosum</i>	whole plant	4.3	10	8	10
<i>Alpinia purpurata</i>	stem	5.9	10	12	15
<i>Artocarpus incisus</i>	male and female flowers	6.3	0	11	not tested
<i>Bryophyllum pinnatum</i>	bark	5.2	0	8	10
	leaf	4.8	0	8	10
<i>Acacia Koa</i>	true leaves	5.5	13	0	0
	phyllodes	5.6	16	0	0
<i>Tamarindus indica</i>	leaves and stems	3.8	12	0	not tested
<i>Aleurites moluccana</i>	leaves and stems	5.8	10	0	0
	flowers	5.0	10	0	0
	leaves only	6.4	10	0	0
<i>Euphorbia pulcherrima</i>	floral parts	5.1	0	0	12
	leaves and stems	5.5	0	0	12
<i>Euphorbia Milii</i>	leaves	4.9	10	0	0
	stems	5.6	10	0	0
<i>Euphorbia Tirucalli</i>	stems	4.5	15	8	8
<i>Mangifera indica</i>	leaves	5.2	12	? (discolored)	not tested
	bark and stems	4.8	11	? (discolored)	not tested
	fruit, small, green	3.5	18	16	not tested
	fruit, half-ripe	3.2	13	15	9
<i>Passiflora</i> sp.	leaves and stems	6.1	12	10	0
<i>Punica Granatum</i>	fruit, seeds*	3.8	14	0	11
<i>Terminalia Catappa</i>	leaves and stems	4.8	18	0	0
<i>Eucalyptus</i> sp.	leaves and stems	4.8	13	0	0
<i>Eugenia Cumini</i>	leaves	5.0	17	12	0
	stems	5.0	15	0	0
	buds and flowers	4.5	15	0	0
<i>Eugenia malaccensis</i>	leaves*	3.4	12	11	11
	fruits (without seed)	4.5	14	18	0
<i>Metrosideros macroopus</i>	leaves and buds	4.3	18	17	18
<i>Psidium Guajava</i>	fruit*	3.5	18	16	not tested
<i>Ipomoea Batatas</i>	stem	6.7	18	0	not tested
<i>Solanum nodiflorum</i>	green fruit	4.6	0	0	10
	ripe fruit*	4.7	0	0	18
	leaves and stems	5.8	10	10	0
<i>Solanum sodomaeum</i>	leaves	5.6	10	0	0
	stems	5.6	10	0	0
	fruits	5.1	10	0	0
<i>Plantago major</i>	whole plant*	5.5	11	10	not tested
<i>Morinda citrifolia</i>	ripe fruit*	4.4	15	10	15
<i>Scaevola Gaudichaudiana</i>	stems	5.9	16	0	0
	fruits and flowers	5.7	13	0	0
<i>Bidens pilosa</i>	whole plant*	5.8	15	15	12

\* See Table 6.

nature of the substances which are present in the plant juices. In other words, and as herbalists and pharmacëutists long ago realized, it is the possession of chemical properties peculiar to itself that makes a plant different from its neighbors and superior to some of them for use as a medicine. The medicinal plants in Hawaii are no exception to this obvious rule. We are not able to say what substances in the tissues of the more effective of the Hawaiian plants are responsible for their efficacy.

The results of the tests with the actual extracts show that of the 101 species studied, 13 possess a considerable degree of effectiveness against the test bacteria (Table 3). Four of these plants—*koa*, *Acacia Koa*; mountain apple, *Eugenia malaccensis*; *ohia lehua*, *Metrosideros macropus*; and guava, *Psidium Guajava*—the Hawaiians have employed in the treatment of cuts and wounds and "skin diseases," or of bacterial infections like "diarrhoeas and dysenteries," but most of the others are plants which do not appear to have played much of a part in the treatment of conditions caused by bacteria. Most of them—*Alpinia purpurata*, *Tamarindus indica*, *Citrus aurantifolia*, *Hura crepitans*, the three *Passiflora* species, and *Punica Granatum*—do not seem to have been used at all by the Hawaiians, possibly because of their relatively re-

cent introduction into Hawaii. One plant, the *uluhe*, *Dicranopteris linearis*, was used by the Hawaiians as a laxative, but not, as far as we know, in the treatment of conditions in which bacteria were implicated as the causative agents. All of these plants are worthy of further study to see if it is possible to obtain from any of them a useful antibacterial substance.

An even greater number of plant species is moderately effective in the action against the test bacteria (Table 4). Among these are several of the more famous and the more favored of the Hawaiian remedies: the *kukui*, *Aleurites moluccana*; the *popolo*, *Solanum nodiflorum*; the *noni*, *Morinda citrifolia*; the *laukahi*, *Plantago major*; and *Bidens pilosa*, a relative of the native "tea," *ko'oko'olau*. All of these plants had a great number of uses in Hawaiian medicine, and the *popolo* in particular has been called "ke kumu o ka lapaau o Hawaii nei"—"the foundation of Hawaiian pharmacy" (Handy *et al.*, 1934: 18). The juices of its leaves and berries were used, either alone or in combination with other ingredients, for diseases of the skin, in the treatment of cuts and wounds, in "disorders of the respiratory tract," and for "toning up the digestive tract" (Handy *et al.*, *loc. cit.*).

Our studies showed that each of the favor-

TABLE 5  
EXTRACTS WHICH EXHIBIT SLIGHTLY EFFECTIVE ANTIBACTERIAL PROPERTIES  
(with zones of inhibition less than 10 mm. in diameter)

NAME OF PLANT	PART OF PLANT PROVIDING EXTRACT	pH OF EXTRACT	DIAMETER OF ZONES OF INHIBITION M.		
			<i>M. pyogenes</i>	<i>E. coli</i>	<i>Ps. aeruginosa</i>
<i>Cibotium Chamissoi</i>	stems of fronds	5.1	0	0	8
<i>Bambusa</i> sp.	leaves and stems	qns	7	0	0
<i>Peperomia latifolia</i>	whole plant	5.7	0	0	8
<i>Pittosporum Tobira</i>	bark*	6.2	0	0	8
	leaf*	6.1	0	0	9
<i>Sida fallax</i>	stems	6.2	9	0	0
<i>Waltheria americana</i>	water extract of leaves and stems	5.5	0	0	8
<i>Eugenia malaccensis</i>	stems	4.3	8	0	0
<i>Lantana Camara</i>	leaf	7.3	8	0	not tested

\* See Table 6.



its plants listed in Table 4 exerts some effect, at least *in vitro*, against representatives of bacterial agents of disease. Perhaps, as the users of these simples were daring enough to learn, they are even more effective when they are applied to the diseased body, when the body can contribute the weapons in its own armory to the attack upon the invading bacteria. Perhaps, too, when they are compounded with other herbs in the complex recipes which many of the *kahunas* prescribed, the total effect of the combination of ingredients is superior to the effect of each of the recipes' components.

Here is one of the simpler prescriptions, taken from the wonderfully naïve herbal of Kaaiakamanu and Akina (1922: 57):

"For scrofulous sores, bad cases of ulcer, and other bad sores where the flesh seems to rot away, the following mixture is recommended: Take the meat of eight *kukui* nuts and have it baked in *ki* leaves until thoroughly cooked. This is pounded or finely ground and then set to one side. About a tablespoonful of the breadfruit milk is then secured and mixed with the prepared *kukui* meat. In the meantime about a spoonful of the finely ground *Cyperus laevigata* fibers [*ahuawa*] and a like amount of the *lama* powder [*Maba* spp.] are being thoroughly mixed. The two mixtures are then put together and thoroughly stirred and applied by spreading it [*sic*] over the sore or sores. This is done morning and evening and as long as necessary.

"Before the treatment, however, the sore should be washed with the tea of the *Bobea* spp. bark [*abakea*] thoroughly cooked with about a gallon of water and with four red hot stones. The bark should be pounded before boiling it in order to get its strength."

Table 5 gives the information concerning the relatively few plant extracts which were only slightly effective against the test bacteria. A few of them are extracts from parts of plants which, in others of their parts, are

much more effective against the test bacteria, but most of them are examples of mediocrity in performance that would sadden the heart of a *kahuna lapaa*.

The following extracts exhibited no apparent antibacterial properties: *Gracilaria furcellata* (whole plant, 5.9<sup>3</sup>); *Psilotum nudum* (tea, 5.2); *Nephrolepis biserrata* (leaves, 5.3); *Freycinetia arborea* (leaves, 5.9); *Pandanus Rockii* (ripe fruit, 5.1); *Coix lacrymajobi* (whole plant, 5.6); *Saccharum officinarum* (leaves, 5.4; stems, 5.1); *Setaria palmifolia* (whole plant, 6.0); *Stenotaphrum secundatum* (leaves, 6.1; stems and roots, 6.0); *Scirpus validus* (whole plant, 6.7); *Cocos nucifera* (milk from nut, 6.7); *Alocasia macrorrhiza* (leaves, 6.0; stems, 5.8; corms and roots, 5.8); *Colocasia esculenta* (corm, 7.0); *Commelina diffusa* (whole plant, 5.4); *Cordyline terminalis* var. *Ki* (leaves and stems, 5.8); *Dioscorea alata* (tuber, 5.7); *Musa paradisiaca* ssp. *sapientum* var. (stem, 5.7; leaf, 6.2; flower bud, 5.0); *Hedychium coronarium* (roots, 6.4; leaves and stems, 6.1; buds and flowers, 6.1); *Zingiber Zerumbet* (root, 6.0; leaves and stems, 5.8; buds and flower-stalks, 6.0); *Casuarina equisetifolia* (leaves and stems, 5.1; cones, 4.5; alcoholic extract of leaves and stems, ?); *Peperomia membranacea* (whole plant, 6.0); *Artocarpus incisus* (leaves and stems, 6.2); *Morus alba* f. *nigrobacca* (leaves and stems, 6.3); *Tournefortia latifolia* (bark, 6.0; stems, 6.2; leaves, 6.8); *Santalum album* (leaves and stems, 6.0); *Amaranthus spinosus* (whole plant, 6.2); *Mirabilis Jalapa* (leaves, stems, and flowers, ?; aqueous solution of seed-powder, ?); *Batis maritima* (whole plant, 5.5); *Portulaca oleracea* (whole plant, 4.5); *Nasturtium officinale* (whole plant, 4.7); *Rubus rosaefolius* (leaves and stems, 6.4); *Acacia confusa* (leaves, stems, and flowers, 5.5); *Cassia Leschenaultiana* (whole plant, 5.8);

<sup>3</sup>Figures in the parentheses indicate the pH of the respective extracts.



*Crotalaria incana* (leaves and stems, 5.9; seeds and pods, 5.9); *Crotalaria mucronata* (whole plant, 6.4); *Dioclea violacea* (leaf, 5.7; seed, 6.2); *Loucaena glauca* (pods, flowers, leaves, and stems, ?); *Medicago sativa* (leaves, stems, and flowers, 5.6); *Prosopis chilensis* (leaves and stems, 5.5; pods and leaves, 5.6); *Vigna marina* (whole plant, 6.0); *Pelea* sp. (leaf, 5.7); *Aleurites moluccana* (young nuts, raw, 6.3); *Euphorbia hirta* (whole plant, 5.6); *Hura crepitans* (leaves and stems, 5.2); *Ricinus communis* (leaves, 6.0; stems, 5.4; seeds, 5.9); *Mangifera indica* (fruit, ripe, 4.7); *Schinus terebinthifolius* (leaves, 4.7; berries, 5.2); *Cardiospermum Halicacabum* (leaves and stems, 6.0; fruits, 5.7); *Dodonaea viscosa* (leaves, 5.5); *Hibiscus tiliaceus* (leaves and stems, 6.2); *Malvastrum coromandelianum* (whole plant, 5.5); *Sida fallax* (leaves, ?); *Waltheria americana* (leaves and flowers, 5.5; stems, 5.5; roots, 5.8); *Calophyllum Inophyllum* (leaves, 4.8; flowers, 4.1; fruits, 5.0); *Passiflora edulis* f. *flavicarpa* (leaves and stems, 5.8); *Passiflora foetida* var. (leaves and stems, 5.5); *Carica Papaya* (leaves, 6.1; flowers, 6.2; fruit, 5.8; seeds, 5.9); *Opuntia megacantha* (leaf-pads, 4.3); *Wikstroemia oahuensis* (leaves, 6.0; stems, 6.1); *Nerium Oleander* (leaves and stems, 5.6; flowers and pods, 5.3); *Thevetia peruviana* (flowers, 6.7; leaves, 6.0; fruits, 7.1); *Ipomoea Batatas* (leaves, 7.1); *Ipomoea congesta* (whole plant, 5.5); *Ipomoea pes-caprae* (leaves and stems, 6.1; flowers and buds, 5.9); *Messerschmidia argentea* (leaves and stems, 6.0; fruits, 6.5); *Stachytarpheta cayennensis* (leaves, 6.1; stems, 6.0); *Capsicum frutescens* (leaves and stems, 5.8; tea from pods, 6.8); *Lycopersicon esculentum* ssp. *Galenii* (leaves and stems, 5.8; fruits, 4.5); *Plantago lanceolata* (whole plant, 5.5); *Morinda citrifolia* (leaves and stems, 5.1); *Momordica Charantia* (leaves, 7.3); *Scaevola frutescens* var. *sericea* (leaves and stems, 6.2; ripe fruit, 5.5); *Scaevola Gaudichaudiana* (leaves, 5.9); *Erigeron albidus* (whole plant, 5.7).

The text listing on page 179 is significant chiefly for its length. In it are included some of the species of plants which the Hawaiians often employed to treat conditions which we now recognize as bacterial infections. Among these plants are sugar cane, *Saccharum officinarum*; buffalo grass, *Stenotaphrum secundatum*; awapubi, *Zingiber Zerumbet*; alalawainui, *Peperomia* spp.; alani, *Pelea* sp.; aalii, *Dodonaea viscosa*; uhaloa, *Waltheria americana*; the poisonous akia, *Wikstroemia oahuensis*; the deadly oleanders, *Nerium Oleander* and *Thevetia peruviana*; sweet potato and the koali of several kinds, *Ipomoea* spp.; chili pepper, *Capsicum frutescens*; naupaka, *Scaevola* spp.; and many others, but, it must be pointed out, there are also included in the list a number of species of plants which were applied by the Hawaiians to the treatment of conditions other than those caused by bacteria. It is worthy of note that, in general, the pH values of the extracts of these plants are significantly higher (that is, less acid) than are the pH values of the more effective plant extracts listed in Tables 3 and 4.

Nevertheless, this list is one of disappointments, from the bacteriologists' point of view, and reveals the price of empiricism in medicine—many failures for every success.

Table 6 is in the nature of an appendix to Tables 3 to 5. It presents the effects of extracts from 17 different plants upon the 5 strains of pathogenic intestinal bacilli used in these studies. Four of the plants were very effective in their antibacterial action and might well be studied further. Only one of these, the guava, *Psidium Guajava*, was used by the Hawaiians specifically for its curative value in "diarrhoeas and intestinal hemorrhages" (Kaaikamanu and Akina, 1922: 55). This illustrates the ability of the Hawaiian to exploit newly introduced plants for his medicinal needs, for the guava was not brought to Hawaii until early in the nineteenth century, when Don Marin im-



TABLE 6  
ACTION OF CERTAIN PLANT EXTRACTS UPON FIVE ENTERIC PATHOGENS \*

ACTION	NAME OF PLANT	PART OF PLANT	pH OF EXTRACT	ZONE OF INHIBITION (IN MM.)				
				<i>Salmonella typhosa</i>	<i>Salmonella montevideo</i>	<i>Salmonella schottmuelleri</i>	<i>Shigella parady.</i> BH	<i>Shigella parady.</i> III-Z
VERY EFFECTIVE	<i>Punica Granatum</i>	whole fruit	3.5	20	18	27	17	12
	<i>Eugenia malaccensis</i>	bark	5.9	0	0	0	20	20
		leaves	5.4	0	0	0	30	35
MODERATELY EFFECTIVE	<i>Psidium Guajava</i>	fruit	3.5	20	19	18	22	30
	<i>Morinda citrifolia</i>	ripe fruit	4.4	23	10	12	22	20
		young fruit	5.2	10	0	0	15	15
SLIGHTLY EFFECTIVE	<i>Momordica Charantia</i>	leaves	7.3	8	0	0	12	12
	<i>Bidens pilosa</i>	whole plant	5.8	17	8	8	8	8
	<i>Pittosporum Tobira</i>	bark	6.2	10	8	0	8	8
		leaves	6.1	8	8	0	8	8
	<i>Solanum nodiflorum</i>	ripe fruit	6.2	8	8	8	8	8
	<i>Plantago major</i>	whole fruit	7.0	8	7	9	8	8

\* The following extracts were found to be ineffective against the enteric pathogens: *Colocasia esculenta* (corm, 7.0); *Commelina diffusa* (whole plant, 5.4); *Dioscorea alata* (tuber, 5.7); *Musa paradisiaca* ssp. *sapientum* var. (stems, 5.7; leaves, 6.2; flower bud, 5.0); *Pelea* sp. (leaves, 5.7); *Schinus terebinthifolius* (leaves, 4.7; berries, 5.2); *Dodonaea viscosa* (leaves, 5.5); *Psidium Guajava* (leaves and flowers, ?); *Ipomoea congesta* (whole plant, 5.5); *Morinda citrifolia* (leaves and stems, 5.1).

ported it (Neal, 1948: 555). (It could not have come too soon for the dying Hawaiian race, for by this time the bloody fluxes, introduced by almost every vessel calling at Hawaii, had long since begun to take their toll of native lives, and the surviving Hawaiians must have been seeking desperately for remedies against them.)

It is possible that many of the other plants which were not tested for their action upon these enteric pathogens will possess properties antagonistic to them. A minor but interesting phenomenon is the apparent selective action of some of these plant extracts upon some of the intestinal pathogens: the action of *Eugenia malaccensis*, for example, is directed against the two *Shigella* strains only; and the young fruit of the *noni*, *Morinda citrifolia*, also exhibits its peculiar selectivity for the two *Shigella* strains and the typhoid bacillus.

Most of the plant extracts listed on page 179, far from inhibiting the test bacteria,

markedly stimulated their growth. Many of the plant extracts which showed some degree of effectiveness against the test bacteria also stimulated the growth of the bacteria in those areas around and beyond the periphery of the zones of inhibition. This action probably can be attributed to the presence of foodstuffs and of growth-promoting factors in the extracts, even in those extracts which also possess agents which are antagonistic to the bacteria. It is also possible that, as is known to be the case with many substances, the same agent in a plant extract may be inhibitory, or even bactericidal, in high concentrations and stimulating in low concentrations.

It must be remembered, too, that the efficacy of these extracts is dependent to a considerable extent upon the diffusability of their component parts. It is, therefore, highly probable that other results might be obtained if other methods of assay were employed, or that many more of the plants might be shown to have a greater degree of effectiveness

against the bacteria if their extracts were treated in such a manner as to purify or to concentrate the antagonistic agents.

In those few instances in which subcultures were taken from the zones of inhibition, the effect of the plant extracts seemed to be a bactericidal one. This claim cannot be made for all the effective extracts inasmuch as we did not prepare subcultures from all the zones of inhibition.

It should be stated here that the studies reported in this paper are merely preliminary investigations into the effectiveness *in vitro* of extracts of plants represented in the Hawaiian pharmacopeia. They are in no sense an endorsement of the *kahuna lapaau laau's* methods or a recommendation of some of these plants for popular usage today. Neither are they to be construed as a defamation of the medical folklore of Hawaii. They are merely a search for facts, upon which some day a scientific appraisal of the Hawaiian's medicines can be based, and out of which, perhaps, a useful therapeutic may emerge.

#### SUMMARY

Preliminary investigations into the antibacterial properties of extracts from different portions of 101 species of plants which have been used in Hawaii for various medicinal purposes showed that extracts from 13 species possessed agents which were very effective *in vitro* in their action against test strains of *Micrococcus pyogenes* var. *aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. Extracts from 30 species of plants (some of the extracts being obtained from parts of the same plants other parts of which exhibited very effective antibacterial action) possessed agents which were moderately effective. The rest were either ineffective or only slightly effective in their action. Determinations of effectiveness were made by testing extracts by the Oxford cup method developed for the assay of penicillin. Extracts were obtained by

submitting freshly collected plant material to pressures of 15,000 to 20,000 pounds per square inch, achieved by means of a Carver hydraulic press.

Extracts obtained from the following plants were the most effective: *ulube*, *Dicranopteris linearis*; red ginger, *Alpinia purpurata*; *koa*, *Acacia Koa*; tamarind, *Tamarindus indica*; lime, *Citrus aurantifolia*; sand-box, *Hura crepitans*; three species of passion fruit, *Passiflora edulis* f. *flavicarpa*, *P. foetida* var., and *Passiflora* sp.; pomegranate, *Punica Granatum*; mountain apple or *obia ai*, *Eugenia malaccensis*; *obia lehua*, *Metrosideros macropus*; and guava, *Psidium Guajava*.

Extracts of 17 of the plants were studied for their effect upon 5 strains of pathogenic enteric bacilli (*Salmonella typhosa*, *Sal. montevideo*, *Sal. schottmuelleri*, and two serological types of *Shigella paradysenteriae*). Extracts from four plants—*Punica Granatum*, *Eugenia malaccensis*, *Psidium Guajava*, and *Morinda citrifolia*—appear to possess agents which are effective against some or all of the intestinal pathogens tested.

Of the plant families studied, species of the Punicaceae, Passifloraceae, Euphorbiaceae, and Myrtaceae appear to be most effective in their antibacterial action, and invite further investigation both for themselves and for other species included in these families.

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# Some Stratiomyidae (Diptera) from Okinawa and Guam

MAURICE T. JAMES<sup>1</sup>

THE PRESENT PAPER is based on the study of a collection of Stratiomyidae from Okinawa and from Guam and the neighboring island of Rota, and now preserved in the United States National Museum and the California Academy of Sciences.

## SPECIES FROM OKINAWA

### *Wallacea albiseta* de Meijere

*Wallacea albiseta* de Meijere, 1907, Tijds. v. Ent., 50: 236.

*Material examined:* Okinawa, June to August, 1945 (W. D. Field, F. N. Young, G. E. Bohart, C. L. Harnage), 9 females, 19 males.

This widely distributed species has been misdetermined as *W. argentea* Doleschall by Brunetti and other authors.

### *Oploodontha rubrithorax* (Macquart)

*Odontomyia rubrithorax* Macquart, 1838, Diptères exotiques nouveaux ou peu connus, vol. 1, pt. 1, p. 185.

*Material examined:* Okinawa, July to September, 1945 (F. N. Young, W. D. Field, R. Bohart), seven males, two females.

### *Sargus mactans* Walker

*Sargus mactans* Walker, 1860, Proc. Linn. Soc. London, 4: 97.

*Material examined:* Chizuka, Okinawa, July to September, 1945 (G. E. Bohart, C. L. Harnage), one male, two females.

### *Ptecticus okinawae* new species

*Male:* Head mainly yellow, with golden pile; frontal callus whitish; occiput black, subshining, with whitish pollen toward the orbits. Antenna structurally as in *P. aurifer* (Walker), yellow, the flagellum dulled with whitish pollen; arista brownish-yellow at extreme base, otherwise black. Mesonotum, scutellum, and postscutellum brownish with bluish to violaceous reflections, paler laterally; thorax otherwise reddish-yellow, the areas adjoining the sutures paler; pile golden except a tuft of short black hairs above the base of each haltere. Halteres yellow; legs uniformly reddish-yellow, the middle and hind femora with slight bluish reflections; pile of legs yellow. Wing venation as in *aurifer*; anterior part of wing as far apicad as vein R<sub>4</sub> and enclosing and extending beyond the discal cell yellow; wing apex and posterior half of wing uniformly grayish and contrasting with the yellow area; veins yellow in yellow area, brownish-black in gray area. Abdomen reddish-yellow in ground color but with large, poorly defined areas taking in all but posterior and lateral margins of terga one to four and of sterna four and five, brownish-black, with bluish to violaceous reflections; pile of first five terga mostly short, black; lateral and apical margins of these terga, as well as entire venter and genital segments, with golden pile. Genitalia reddish-yellow. Length, 14 mm.

*Holotype:* Male; Chizuka, Okinawa; July to September, 1945 (G. E. Bohart, C. L. Harnage); California Academy of Sciences.

Related to *P. aurifer* (Walker), but easily distinguishable by the lack of contrast between the gray area of the apex and of the

<sup>1</sup>Department of Zoology, State College of Washington, Pullman, Washington. Manuscript received August 29, 1949.



posterior half of the wing; in *aurifer*, the apex is distinctly darker and this area is sharply defined from both the anterior yellow and the posterior gray areas. In size, *aurifer* is normally larger (17 to 22 mm. in length), the upper parts lack the bluish reflections, and the fifth abdominal segment, though variable, is marked with black. I can find no structural differences; the genitalia seem to be identical.

### *Ptecticus australis* Schiner

*Ptecticus australis* Schiner, 1868, Novara Reise, Diptera, p. 65.

Originally described from the Nicobar Islands, this species has been recorded from Ceylon, Siam, Malaya, and various Indian localities by Brunetti, and I have seen it from Palawan, Philippine Islands. One female and five males from Chizuka, Okinawa, July to September, 1945 (G. E. Bohart, C. L. Harnage), represent a form with the hind legs somewhat paler than in the typical form; the tibia and base of the basitarsus are brown rather than black, though these areas distinctly contrast with the yellow of the hind femur and the white of the remainder of the hind tarsus. Otherwise, I note no significant difference from Indian and Philippine specimens.

### *Ptecticus tenebrifer* (Walker)

*Sargus tenebrifer* (Walker), 1849, List of the specimens of Dipterous insects in the collection of the British Museum, pt. 3, p. 517.

This common Oriental and southeastern Palaearctic species is represented by a long series of males and females from Chizuka, Okinawa.

#### SPECIES FROM GUAM AND ROTA

### *Paracechorismenus guamae* new species

*Female*: Head shining black. Vertex two-fifths head width, narrowing to the nearly

parallel-sided front; front at narrowest equal to distance from anterior ocellus to the antennal insertion. Face with a few whitish hairs and with conspicuous whitish-tomentose orbits. Head profile essentially as in *intermedius* Kertész, except that the ocellar triangle is not quite so prominent. Antennae yellow, the flagellum above and the arista brownish-black; arista 1.65 length of rest of antenna. Proboscis yellow. Measurements of holotype in micrometer units ( $85 = 1$  mm.): Width of head, 50; of vertex, 20; of front at narrowest part, 13; front, anterior ocellus to antennal insertion, 13; length of antenna excluding arista, 12; of arista, 20.

Thorax black, subshining; mesonotum and scutellum with conspicuous, rather dense, golden tomentum; posterior area of mesopleuron with similar yellow tomentum. Legs uniformly yellow, at most slightly darkened toward apices of tarsi. Halteres yellow. Wing venation typical; wings slightly clouded; heavy veins brown; veins inclosing discal cell, except at base, and those radiating from it, weak and unpigmented.

Abdomen black; pile mostly black, inconspicuous, that on fifth tergum and laterally on third and fourth terga somewhat longer and yellowish. Ovipositor yellow.

Length, 1.75 to 2.5 mm., mostly about 2 mm.

*Male*: Front narrower than in the female, at narrowest 0.18 to 0.20 head width and 0.65 to 0.70 distance from anterior ocellus to antennal insertion. Tomentum of mesonotum and scutellum longer but more scattered than in the female, tending more to whitish but with golden tomentum definitely intermixed and usually predominating. Genitalia yellow. Otherwise, as described for the female.

*Holotype*: Female, Guam, January 12, 1938 (R. G. Oakley); resting on *Ochrosia* fruits; Guam no. 1206; Lot no. 38-14973; U. S. National Museum type no. 59339. *Allotype*: Male, Point Oca, Guam, May,

1945 (G. E. Bohart, J. L. Gressitt). *Paratypes*: Seventeen females, fourteen males, same data as holotype; seven females, five males, same data as allotype; one male, one female, Point Oca, Guam, December 20, 1945 (Gressitt); one male, Asan, Guam, December 16, 1945 (Gressitt); two females, Point Oca, near Agana, Guam, May 27, 1945 (Gressitt), at lights; one female, Point Riti-dian, Guam, June 28, 1945 (Bohart & Gressitt); two females, one male, Namru 2, Guam, May 7, 1945 (Gressitt).

In Kertész' key (Mus. Nat. Hungarici Ann. 14: p. 163, 1916), this species does not run past the first couplet, since the antennal flagellum is distinctly darkened above, but the arista is much longer than the rest of the antenna and the legs are almost unicolorous. The relationship is probably closest to *P. intermedius* Kertész, from Formosa, but in that species the antenna is wholly yellow, the femora are darkened on the apical third, and the mesonotal pile, anteriorly and on the swellings behind the suture, is blackish.

#### *Wallacea albiseta* de Meijere

*Wallacea albiseta* de Meijere, 1907, Tijds. v. Ent., 50: 236.

*Material examined*: Point Oca, Guam, May, 1945 (G. E. Bohart, J. L. Gressitt), two females, one male.

#### *Cephalobrysa infuscata* new species

*Female*: Head about 1.65 times as wide as high. Front at upper corner of eyes about one-third head width, narrowing gradually to the face, which is nearly parallel-sided on its lower part; front metallic bluish with lavender reflections, finely punctured and with fine pale hairs arising from the punctures, except along the narrow median line where it is slightly raised and glabrous, and more particularly at the anterior extremity of this line, where the glabrous areas are expanded into an inverted V; frontal callus entire, forming

a transverse band which is biarcuate above, as a result of the V-shaped glabrous area; the callus whitish above, brownish below as it merges into the brownish-black of the face. Occipital orbits broad above, blue with lavender reflections and with punctures as on the front, becoming narrow and blackish below. Comparative measurements in micrometer units ( $30 = 1$  mm.), based on holotype: Head width, 69; head height, 42; width of front, upper angle of eyes, 23; width of front, upper margin of callus, 20; width of face, 15; maximum width of occipital orbit, 9. Occiput black, with bluish reflections above. Antennae reddish-yellow; proboscis pale yellow.

Mesonotum and scutellum chiefly metallic blue, with violet reflections and with short, appressed pale pile; humeri and notopleural margin yellow, however, and postalar calli and apex of scutellum reddish-yellow, the postalar calli with black hair. Postscutellum and upper pleural areas largely metallic blue; lower pleural areas largely black but becoming yellowish in irregular and variable areas on the pteropleura and sternopleura.

Coxae, femora, hind tibia, upper surface of hind tarsus, and basal half of front and middle tibiae, especially above, blackish; all these segments usually paler basally and apically; legs otherwise yellow or yellowish. Wings infuscated, especially through the discal cell and thence along the anterior part of the apical half of the wing, the stigma the darkest; veins blackish.

Abdomen distinctly broader than the head or thorax, metallic green to blue above, with violet or purple reflections, especially on the sides or ventrally.

Length, 6–7.5 mm.; of holotype, 7 mm.

*Male*: Eyes, as usual, broadly contiguous. Legs more extensively pale than in the female but with the middle and hind femora, the basal half of the middle and hind tibiae, and the hind tarsi, particularly above, blackish. Wings infuscated as in the female. Ab-



domen distinctly narrower than head; pile more prominent, particularly anteriorly; venter with an extensive yellow median area on segments one to three. Genitalia yellow.

*Holotype*: Female, Guam, on *Ochrosia* fruit, July 25, 1938 (R. G. Oakley); Guam no. 1205; Lot no. 38-14972; U. S. National Museum type no. 59338. *Allotype*: Male, same data. *Paratypes*: One male, five females, same data; one female, Guam, December, 1945 (R. M. Bohart); one male, one female, Point Oca, Guam, June 6 and 14, 1945 (G. E. Bohart, J. L. Gressitt), at light; one female, Mt. Santa Rosa, Guam, May 16, 1945; one female, native forest near Sabana, Rota Island, 1,200 ft., June 19, 1946 (H. K. Townes).

The infuscated wings, the darkened legs,

and, in particular, the infuscated hind tarsi, and the V-shaped glabrous area on the front of the female will readily distinguish this species from all others known to me. The female of *Cephalochrysa hovas* (Bigot), the genotype, has the front more coarsely punctured except on a raised area next to the median suture; this area is broad and prominent, however, and does not expand below as in *infuscata*. *C. hovas* has been recorded from Hawaii, but the determination may be erroneous. No raised glabrous area occurs on the front of the other Oriental species, *C. chrysidiformis* (Lind.), *C. maxima* (de Meij.) and its variety *demeijerei* (Lind.), or *C. stenogaster* James, or in any of the known American species.

# The Zonation of Marine Algae at Piha, New Zealand, in Relation to the Tidal Factor<sup>1</sup> (Studies in Inter-tidal Zonation 2)<sup>2</sup>

W. A. BEVERIDGE AND V. J. CHAPMAN<sup>3</sup>

## INTRODUCTION

THIS PAPER forms part of an inquiry into the operation of tidal factors in determining littoral zonation, and provides a comparison with work performed on the east coast of the Auckland Province (unpublished). There is still considerable confusion concerning the terminology that should be used in these ecological investigations. One of us (Chapman, 1947) has suggested that the time is now ripe for the application of ecological terms in the sense used by land workers. This viewpoint has been contested recently by Womersley (1947) but on grounds that scarcely seem adequate. In view of this confusion, however, it is still desirable to define the terms used, and in the present investigation they are as follows:

The *littoral* region is regarded as all that part of the shore between highest wash and the lowest level of spring tides. This definition is also adopted by Oliver (1923) and by Cranwell and Moore (1938).

*Formation* is a unit of vegetation formed by the habitat and expressed by distinctive life forms (Tansley, 1944), e.g., the Laminarian formation of Europe and the giant kelp formation of the north Pacific. (Owing to the small area studied formations have not been considered in this paper.)

<sup>1</sup>This paper is a résumé of work carried out by the first author for a Master of Science degree at Auckland University College, Auckland, and has been prepared for publication by the second author.

<sup>2</sup>For Studies in Inter-tidal Zonation 1, see *Pacific Science* 4(1): 63-68, 1950.

<sup>3</sup>Forest Officer in the Malayan Forest Service and Professor of Botany, Auckland University College, respectively. Manuscript received March 29, 1949.

*Association* is the largest unit of the plant formation dominated by more than one species and with at least some subordinate species, the dominants having the same ecological requirements.

*Consociation* is a community characterised by a single major dominant.

*Society* is a subordinate community *within* an association or consociation and characterised by a locally dominant subsidiary species.

*Belt* (*zone* of some authors) is a horizontally extended association which may be continuous round the coast, or which may be interrupted by another community, the presence of which depends on slightly different local conditions.

*Aspect society* is a seasonal community locally dominant.

*Clan* is a small aggregation of subordinate species.

*Fasciation* is a modification of the association in which a secondary species becomes a dominant or co-dominant.

*Exposure* can mean one of two things—exposure to the air during low tide periods or exposure to strong wave action. These two different types of exposure will be designated in the text by the terms *air* and *wave* exposure, respectively.

In this paper the viewpoint is adopted that the biome of the rocky sea shore represents a *physiographic climax*, since it is dependent upon the tide rather than upon the climate.

## LOCALITY

Piha is situated about 7 miles north of the Manukau Heads on the west coast of New Zealand, where there is exposure to the waves





FIG. 1. View of Camel Rock, Piha, from the north. The gap is behind and to the left. The wave-cut platform at the base of the rock is clearly visible.



FIG. 2. Mouth of the gap, south of Camel Rock. Note the sharp upper limit to the algal zonation, most of which is *Durvillea*.



created by the full force of the prevailing westerly winds that blow over the Tasman Sea.

Observations were carried out mainly on Lion Rock and at the "Gap" behind Camel Rock. The former is an isolated rock 330 feet high and has a broad wave platform at about storm height. The sides of this platform slope steeply down to low water mark at most points. The second area is formed by a large off-shore rock (Camel Rock) with a narrow channel between it and the mainland; through this the sea surges with great force. There is also a tunnel through the northern end of Camel Rock in an east-west direction. (Fig. 1.)

Geologically the rocks belong to the Manukau Breccia series and consist of andesitic fragmental beds with numerous intrusive dykes and minor interbedded flows. There is no variation in the area studied.

#### CLIMATE

The climate is mild and equable with prevailing westerly winds, but the open coast is often exposed to strong gales which send the waves to great heights against the vertical cliffs. The sea is seldom calm and there is normally a strong surf, and even on the quietest day a considerable swell is present.

The mean annual precipitation is about 44.73 inches and the mean annual amount of sunshine, 1,914 hours. The average annual air temperature range is 26° C. with a daily shade range of about 7.0° C. The maximum shade temperature is 32.8° C. and the minimum — 0.5° C.

#### LITTORAL COMMUNITIES

These are described more or less from high water mark downwards.

##### 1. *Lichina pygmaea*-*Melaraphe* association

Range: upper limit of spray to M.H.W.S.<sup>4</sup>

*Lichina pygmaea* (d)<sup>4</sup>  
*Melaraphe oliveri* (d)  
*Melaraphe cincta* (d)  
*Entophysalis deusta* (l)  
 various limpets

In positions of maximum wave exposure this association may reach great heights. It is usually absent from crevices and other strongly shaded places. Of the two gastropods *M. oliveri* has the wider range since it may descend to M.H.W.N. whereas *M. cincta* occurs in the lower part of this association and in the narrow band formed by the next community.

##### 2. *Bostrychia arbuscula* consociation

Range: wash of M.H.W.S. to M.H.W.N.

*Bostrychia arbuscula* (d)  
*Rhizoclonium riparium* (lf)  
*Lophosiphonia macra* (lf)  
*Caloglossa leprieurii* (lf)  
*Melaraphe oliveri* (f)  
*Melaraphe cincta* (f)  
*Entophysalis deusta* (seasonal)  
*Enteromorpha ramulosa* (seasonal)

The dominant species occurs on shady exposed rock faces in a permanently juvenile and sterile prostrate form; the adult, dark red, fertile form is to be found in moist and dark crevices.

<sup>4</sup>The following abbreviations are used throughout this discussion:

E.H.W.S. = Extreme high water spring tides.  
 M.H.W.S. = Mean high water spring tides.  
 M.H.W.N. = Mean high water neap tides.  
 E.(L).H.W.N. = Extreme (lowest) high water mark neap tides.  
 M.S.L. = Mean sea level.  
 E.(H).L.W.N. = Extreme (highest) low water mark neap tides.  
 M.L.W.N. = Mean low water neap tides.  
 M.L.W.S. = Mean low water spring tides.  
 E.L.W.S. = Extreme low water spring tides.  
 d = dominant  
 a = abundant  
 f = frequent  
 o = occasional  
 r = rare  
 l = local



The consociation attains its best development amidst boulders at the back of the rock platform or in more sheltered places. *Bostrychia* does not appear able to withstand direct strong wave action. In general this belt occurs below the *Lichina* but above the main development of the barnacle zone.

Under conditions of extreme shade *Bostrychia* is replaced by *Rhizoclonium riparium* above and *Lophosiphonia macra* below. Where the shade is rather less intense *Caloglossa leprieurii* is a common associate. *Entophysalis deusta* occurs on sunny faces in summer and *Enteromorpha ramulosa* in winter.

### 3. Chamaesipho association

Range: M.H.W.S. to M.S.L.

*Chamaesipho columna* (d)  
*Chamaesipho brunnea* (d)  
*Porphyra columbina* (f-l)  
*Modiolus neozelanicus* (f)  
*Elminius plicatus* (f)  
*Centroceras clavulatum*

The configuration of the rock is important in relation to the upward extension of this association. Where the wave platform is bounded by vertical walls the association occurs up to the edge, but where the rock is sloping the surge of the waves elevates the upper limit considerably. *Chamaesipho columna* is most abundant from M.H.W.N. upwards; below it enters into competition with *Modiolus* and *Elminius*. *Porphyra columbina* apparently exists in two forms in this association. The first, which is usually small, tufted, and light green, occupies a belt from H.W.N. to H.W.S., being most abundant in sheltered and sunny areas. From H.W.N. to L.W.N. there is a larger, more flaccid, olive-red form, which, however, grades into the other form where shading occurs. The two forms may therefore represent sun and shade types.

### 4. Modiolus-Chamaesipho columna association

Range: M.H.W.N. to M.L.W.N.

*Chamaesipho columna* (d)  
*Modiolus neozelanicus* (d)  
*Elminius plicatus* (f-la).  
*Centroceras clavulatum*  
 (spring and summer)  
*Gelidium pusillum* (o)  
*Apophloeia sinclairii* (o)  
*Chaetangium corneum* (o)  
*Lophosiphonia macra* (r)

The composition of this association varies, depending on wave action. One may therefore recognise two fasciations. The principal difference is in the greater abundance of *Elminius plicatus* under conditions of moderate wave action, whereas where there is strong wave action this species is restricted to crevices and sheltered areas. In places the *Modiolus* forms a close cover; under these circumstances it appears to be antagonistic to other animals and to plants. Only a few algae appear capable of attaching themselves to the mollusk.

Although this association is here regarded as distinct from the preceding association it must be recognised that some workers might prefer to regard it as a fasciation of the *Chamaesipho* association. It does differ however in the co-dominance of the *Modiolus*, the greater abundance of the *Elminius* under certain circumstances, and in the levels it occupies. It is for these reasons that it is here treated as a separate association.

### 5. Vermilia-Hermella association

Range: M.S.L. to M.L.W.N.

*Vermilia carinifera* (d)  
*Hermella spinulosa* (d)  
*Modiolus neozelanicus* (o)  
*Chamaesipho columna* (o)  
*Gigartina alveata* (o)  
*Gelidium caulacanthum* (o)  
*Centroceras clavulatum*  
 (spring and summer)  
*Pleonosporum hirtum* (o)  
*Caulacanthus spinellus* (f)



This is an association which occurs constantly in all areas except where there is very strong wave action, and which is characterised by a distinctly restricted vertical range (about 18 inches). Both the dominants are important because they eliminate larger algae that otherwise might be present.

6. *Gigartina alveata* consociation (Fig. 3)

Range: M.S.L. to M.L.W.N.

*Gigartina alveata* (d)

*Modiolus neozelanicus* (lf)

*Chamaesipho columna* (f)

*Gelidium caulacanthum* (la)

*Pleonosporum hirtum* (summer)

*Scytothamnus australis* (o)

The consociation forms a compact belt in those places where there is neither strong wave action nor extreme shelter. It always occurs above *Pachymenia himantophora* when both are present. On boulders at the head of gullies the community tends to be closed so that there are very few, if any, associated algae. In wave-exposed situations bleached and stunted specimens of *Gigartina* are scattered sparsely over the rocks.

7. *Pachymenia himantophora* consociation (Fig. 4)

Range: E.(H).L.W.N. to about 12-18 inches below.

*Pachymenia himantophora* (d)

*Lophurella caespitosa* (o)

*Champia novae-zelandiae*

*Gelidium caulacanthum* (o)

The consociation is absent in the more sheltered localities of the open coast, and appears to reach its maximum development in gullies where the plants are exposed to heavy surge as distinct from breaking waves. On the open coast it occurs on the shoreward side of rocks with *Durvillea* at the same level on the seaward side.

8. *Gigartina marginifera* consociation (Fig. 4)

Range: M.L.W.S. upwards for 6-9 inches.

*Gigartina marginifera* (d)

*Stenogramme interrupta* (o)

*Champia novae-zelandiae* (o)

*Carpophyllum maschalocarpus* (l)

The consociation occurs below the *Pachy-*

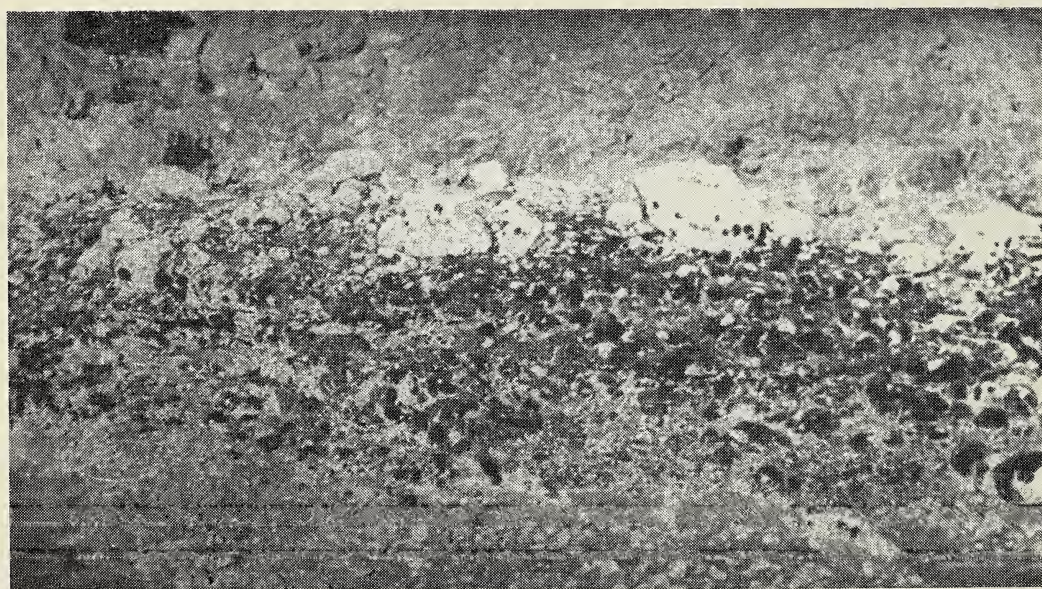


FIG. 3. A view of *Gigartina alveata* consociation with *Modiolus neozelanicus*.



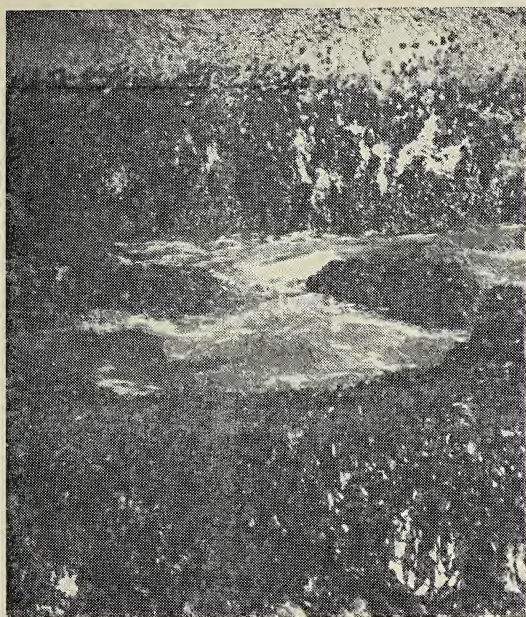


FIG. 4. Algal zonation in a gully to the west of Lion Rock. At the top there is a well-marked zone of *Gigartina alveata*, below a belt of *Pachymenia himantophora* and below that *Gigartina marginifera*.

*menia*, flourishing especially on the flat tops of boulders in strong surge.

#### 9. *Durvillea*-*Mytilus* association

Range: E.(H).L.W.N. to E.L.W.S.

*Durvillea antarctica* (d)

*Mytilus canaliculus* (d)

*Gigartina marginifera* (l)

The association occurs in the form of consociations dominated either by *Durvillea* or by *Mytilus*, because the two species appear to be antagonistic to each other. The upper limit of the *Durvillea* is clearly defined but the lower plants seem to thin out gradually with decreasing power of the surf. The species is essentially surf loving, and in this respect is like *Postelsia* of California. The *Mytilus* consociation is better developed in the more sheltered areas.

#### 10. *Mytilus*-attached algae association

Range: M.L.W.N. to M.L.W.S.

*Mytilus canaliculus* (d)

*Porphyra columbina* (d)

*Ulva rigida* (d)

*Ulva linza* (d)

*Scytothamnus australis* (d)

*Gigartina atropurpurea* (d)

*Gigartina alveata* (o)

*Splachnidium rugosum* (o)

*Laurencia* sp. (o)

*Corallina* sp. (o)

*Centroceras clavulatum* (o)

*Glossophora kunthii* (o)

The association is found on the shallowing floors of small caves, on flat shelves, and on boulders in moderately sheltered areas. The attached algae form colonies on the *Mytilus*, though both *Ulva* and *Porphyra* are capable of colonising the bare rock.

#### 11. *Gigartina* association

Range: M.L.W.N. to M.L.W.S.

*Gigartina atropurpurea* (d)

*Gigartina marginifera* (d)

*Mytilus canaliculus* (o)

*Ulva rigida* (la)

*Laurencia gracilis* (f)

*Champia novae-zelandiae*

*Corallina* spp. (l)

*Plocamium* spp. (l)

The association occurs in moderately sheltered areas, *G. marginifera* tending to dominate seaward and *G. atropurpurea* shoreward. Shifting sand constantly buries parts of the association temporarily and removes the plants by scour. On re-exposure to air *Ulva* quickly recolonises the area but is replaced later by the dominants.

#### LOCAL COMMUNITIES OF THE MID-LITTORAL

#### 12. *Nemastoma oligarthra* society

Range: M.H.W.N. to M.S.L.

The *Nemastoma* society was noted but once in a large gully. It disappeared in winter.

13. *Splachnidium rugosum* society

Range: M.S.L. to L.W.N.

A seasonal community that disappears in winter.

14. *Cladhymenia oblongifolia*-*Schizymenia* sp. association

Range: M.L.W.S. to E.L.W.S.

The association occupies the sublittoral where there is a shallowing shore and a moderate surf. It is to be found from spring to autumn and it reaches its maximum development in summer. *Champia novae-zelandiae* and *Stenogramme interrupta* are common associates.

15. *Vidalia*-*Melanthalia*-*Pterocladia lucida* association

Range: M.L.W.S. to sublittoral.

An association that occurs in long gullies below the *Pachymenia* belt. *Vidalia colensoi* is the dominant near the mouth but it is replaced by *Melanthalia abscissa* and *Pterocladia* near the head.

## 16. Brackish water community

*Enteromorpha ramulosa**Enteromorpha bulbosa**Enteromorpha flexuosa**Enteromorpha nana**Bangia fusco-purpurea**Calothrix* sp.*Rhizoclonium riparium*

The composition of this community varies from place to place.

## 17. Seasonal communities

*Scytosiphon lomentarius* forms an aspect society at L.W.N. during spring but the plants are very small. *Colpomenia sinuosa*, together with *Myriogloia lindaueri*, is also abundant in spring and early summer. *Ilea* (*Phyllitis*) *fascia* is another casual occurring around L.W.N. during winter and spring.

Stephenson (1939) in his work on the zonation of South African shores distinguished three principal zones in the inter-

tidal region: (a) *Littorina* zone; (b) balanoid zone; (c) sublittoral fringe.

It seems that this concept can be well applied to the zonation at Piha. *Melaraphe* is closely allied to *Littorina* and the balanoid zone is well represented by the species of *Chamaesipho* and *Elminius*. The sublittoral fringe can be regarded as extending from M.L.W.S. to E.L.W.S. and is occupied by the *Vidalia*-*Melanthalia*-*Pterocladia*, *Cladhymenia*-*Schizymenia*, *Durvillea*-*Mytilus*, and *Gigartina* associations according to the nature and degree of wave action.

## TIDAL MEASUREMENTS AND PROCEDURE

As no tidal data were available for Piha it was necessary to erect a tide pole and to take a series of readings at high and low water. The tide pole was erected near Camel Rock in a sheltered area with its foundation at approximately E.L.W.S.T. Owing to the surf and swell, readings were restricted to calm days. When the Piha scale had been correlated with the data of the Auckland Harbour Board (A.H.B.) charts, the complete records of the Auckland tides could be used to calculate the tidal phenomena at different levels, especially those that appeared to be highly significant in respect of zonation.

The correlation data showed that on an average both high and low water records at Piha on the arbitrary tide pole scale were 0.98 (= 1 foot) foot below the corresponding levels at Auckland (A.H.B. datum). This indicates also that the tidal range at Piha is approximately the same as that at Auckland (10 feet at average spring tides).

The various fundamental tide levels were calculated using the actual Auckland marigrams for 1945. M.H.S.W., M.L.W.S., M.H.W.N., and M.L.W.N. were obtained by averaging the highest and lowest tides, respectively. The means of the equinoctial high and low spring tides gave E.H.W.S.T. and E.L.W.S.T., respectively. Similarly the figures



for E.(L).H.W.N.T. and E.(H).L.W.N.T. are obtained by calculating the means of the extreme neap tides, i.e., those with the smallest range.

A.H.B. datum  
(feet)

E.H.W.S.T. . . . .	11.94
M.H.W.S.T. . . . .	11.34
M.H.W. . . . .	10.30
M.H.W.N. . . . .	9.26
E.(L).H.W.N. . . . .	8.79
M.S.L. . . . .	6.22
E.(H).L.W.N. . . . .	3.82
M.L.W.N. . . . .	3.24
M.L.W. . . . .	2.14
M.L.W.S. . . . .	1.03
E.L.W.S. . . . .	0.44

ANALYSIS OF THE TIDAL FACTOR

The tidal factor may be considered under three heads:

1. Hours of submergence and air exposure.
2. Periods of continuous air exposure or submergence.
3. Number of submergences and air exposures.

In most cases it is probable that it is a combination of factors that renders a certain level critical insofar as zonation is concerned. In respect to air exposure, the principal effect is the degree of desiccation (in its widest sense) to which the species are subjected. In the case of submergence the amount of incident light becomes important. Also to be considered is the operation of these factors at different periods in the life of the individual plants.

*Level and percentage of annual air exposure (Fig. 5)*

In most cases where tidal factors limit the distribution of a species, the limitation will be due not so much to a gradual change in conditions but to a more or less sudden variation in some factor. In Fig. 5 such changes

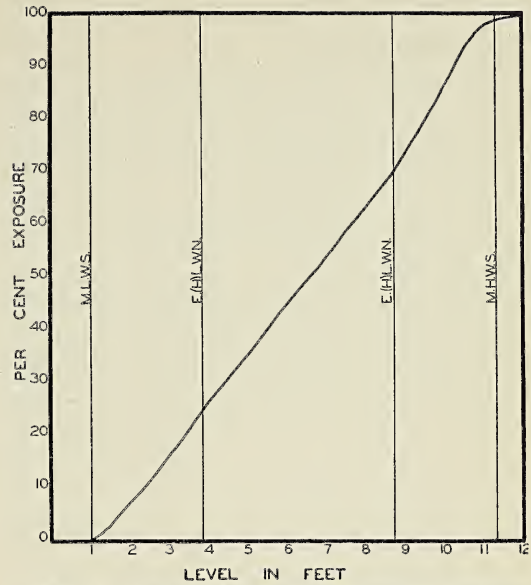


FIG. 5. Graph showing relationship between the level and percentage annual exposure. The major tide levels are also included.

occur at the 1-, 2-, 4-, 10-, and 11-foot levels. A gradual change may, however, be equally important; thus the amount of exposure is trebled between + 2 and + 3 feet. The increase at this level may be far more important than a similar increase at + 9 to 10 feet.

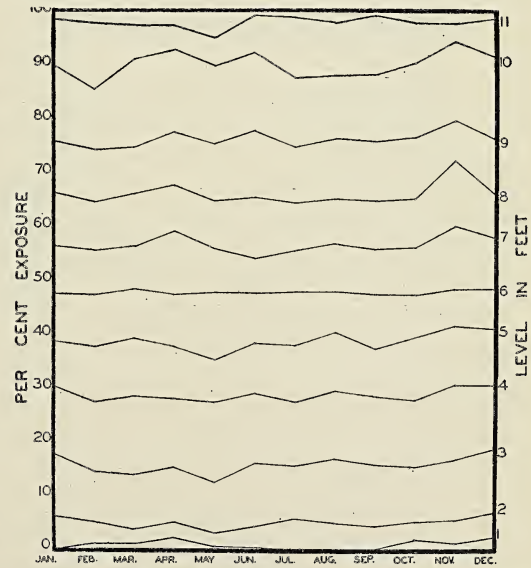


FIG. 6. The relationship between level and percentage monthly exposure.

*Level and percentage of air exposure per month (Fig. 6)*

It will be noted that between + 7 and + 10 feet there is an increase in air exposure in spring and autumn, this rise being most marked at the 10-foot level.

*Level and continuous air exposure and submergence*

This factor may operate either through the total period to which an organism is exposed or through the occurrence of an extensive period at a critical stage in development. Significant changes in the length of the maximum periods occur at + 3 feet and + 10 feet. There is also a slight increase in the total air exposure above the 11-foot level and

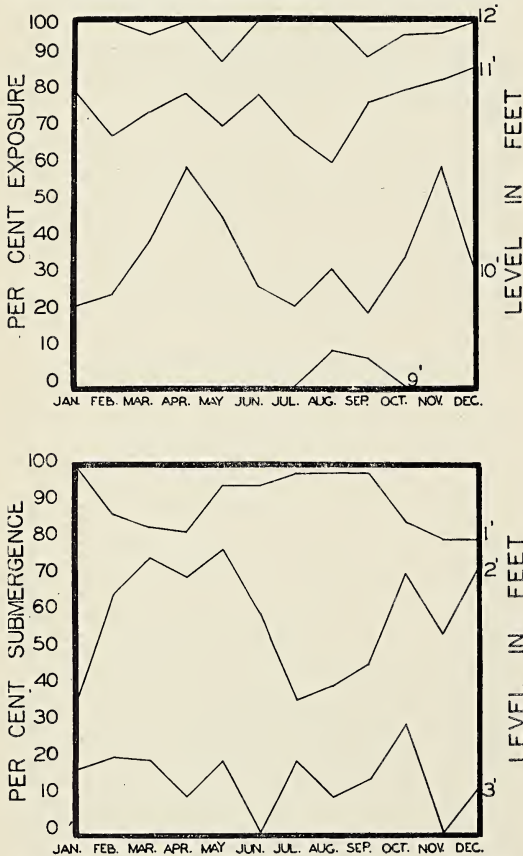


FIG. 7. *Upper.* Relationship between level and percentage continuous (non-tidal) exposure per month. *Lower.* Relationship between level and percentage continuous (non-tidal) submergence per month.

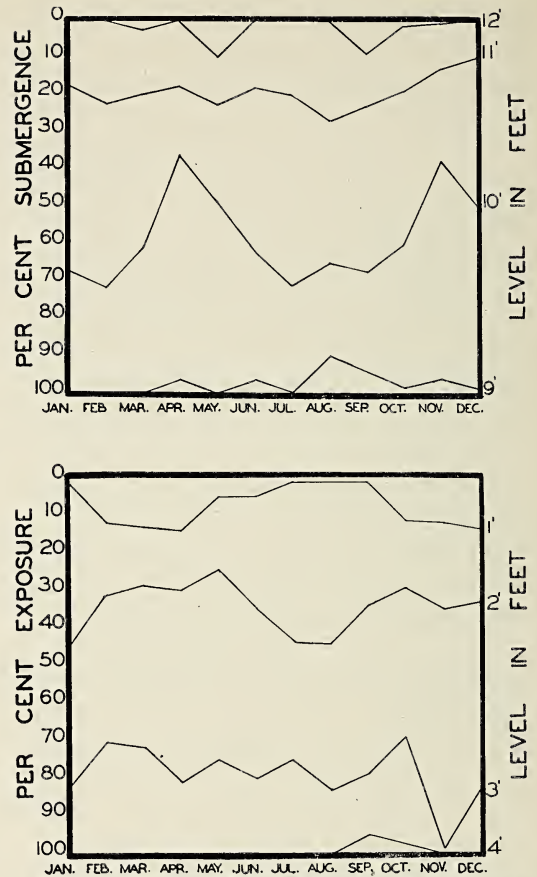


FIG. 8. *Upper.* Percentage monthly submergence at high tides. *Lower.* Percentage monthly exposure at low tides.

an increase in total submergence at + 3 feet. *Level and percentage of continuous air exposure and submergence per month (Fig. 7)*

There are significant changes in continuous air exposure at both the 9- and 10-foot levels. The short periods of continuous air exposure occurring in August and September at the 9-foot level may also be important in determining the upper limits of some of the more sensitive species. At the 2-foot level long submergences occur from February to May but toward winter there is a rapid decrease in length of submergence which may be of significance.

*Percentage of monthly submergences and exposures (Fig. 8)*

From the data given here it may be con-



cluded that species requiring a wetting each day will not grow above the 9-foot level. It will be seen too that the percentage of air exposure increases rapidly between + 2 and + 3 feet. Further, there is a significant decrease in the percentage of submergence between 9 and 11 feet.

An additional factor, that of tidal flow, which has been studied by Elmhirst (1933) and David (ms.), may exert a certain effect around E.(L).H.W.N. and E.(H).L.W.N. This effect is related to regular variations in rate of tidal flow during ebb and flood. Thus from either high or low water the tide runs 7 per cent of its height in the first hour, 18 per cent in the second hour, 25 per cent during each of the third and fourth hours, 18 and 7 per cent during the fifth and sixth hours, respectively.

RELATION OF SPECIES TO TIDE LEVELS

A levelling survey was carried out to determine the upper and lower limits of the more important algal and animal species.

Only the optimum range of a species was measured, stragglers being excluded, and wherever possible levels were obtained that would give a direct expression of the tidal influence. Additional readings were also taken in places where one of the environmental factors brought about a local change in the normal level, either raising the upper limit or depressing the lower limit. The results of the levelling survey are incorporated in a series of diagrams for the different areas where the range (obtained by taking the mean of several levels) has been plotted against tide level.

In a few cases the lower limits of species growing well down on the shore are not known with certainty; this is because the sea is seldom calm at Piha and it is therefore difficult to obtain levels at low water. In these cases observation has had to supplement actual readings. Thus the levels of species growing in the vicinity of the tide pole were compiled from observations made while watching the tide pole. One may also say that up-

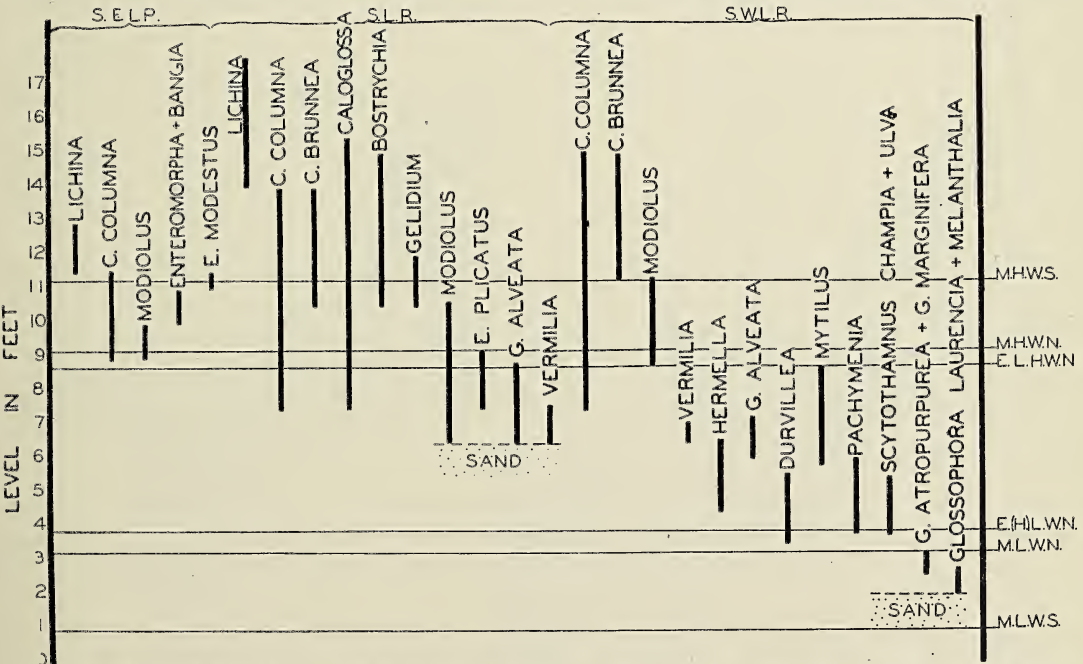


FIG. 9. Vertical distribution of the species southeast of Lion Rock (S.E.L.R.), south of Lion Rock (S.L.R.), southwest of Lion Rock (S.W.L.R.).

per limits of higher species are fairly definite but the lower limits are less pronounced unless there is severe competition.

There is also the problem of thallus length. Thus the long thalli of *Pachymenia* hang down well below the holdfast. Since, however, the sporeling phase is probably the most critical period in the life history of an alga, it is the levels delimited by the holdfasts which should be significant.

If the diagrams (Figs. 9-12) for the various areas are examined it will be seen that two major points are emphasized:

1. The zonation changes with degree and manner of wave action.
2. With increasing exposure to wave action the levels of some species are raised, those higher on the shore being more affected than those lower down.<sup>5</sup> At high levels the upper limit of a species is often elevated more than the lower. Thus in Figure 13 the lower

<sup>5</sup>The height to which breaking waves raise the uppermost tide mark above its predicted or recorded level is referred to as the splash zone.

limit of *Lichina* is raised by some 4 feet. In areas with maximum wave action *Lichina* and *Melastoma* may rise at least 40 feet higher than normal.

In other species, e.g., *Chamaesipho* spp., the lower limit may remain unaffected whereas the upper limit is raised many feet by wave exposure. By contrast, *Vermilia* and *Hermella*, found in more sheltered areas, are apparently independent of wave action.

In the diagrams it will be noted that Lion Rock provides a series of habitats characterized by increasing exposure to wave action and depth of water. The diagrams show that in the different areas most species retain the same relative positions wherever they occur. *Vermilia* and *Hermella* are exceptions because they retain their positions relative to the absolute levels.

Finally, using these diagrams as a basis, an attempt was made to summarize the levelling data after making an allowance for the influence of wave action. The result is depicted in Figure 14. Since each species is affected differently by wave action, each requires a

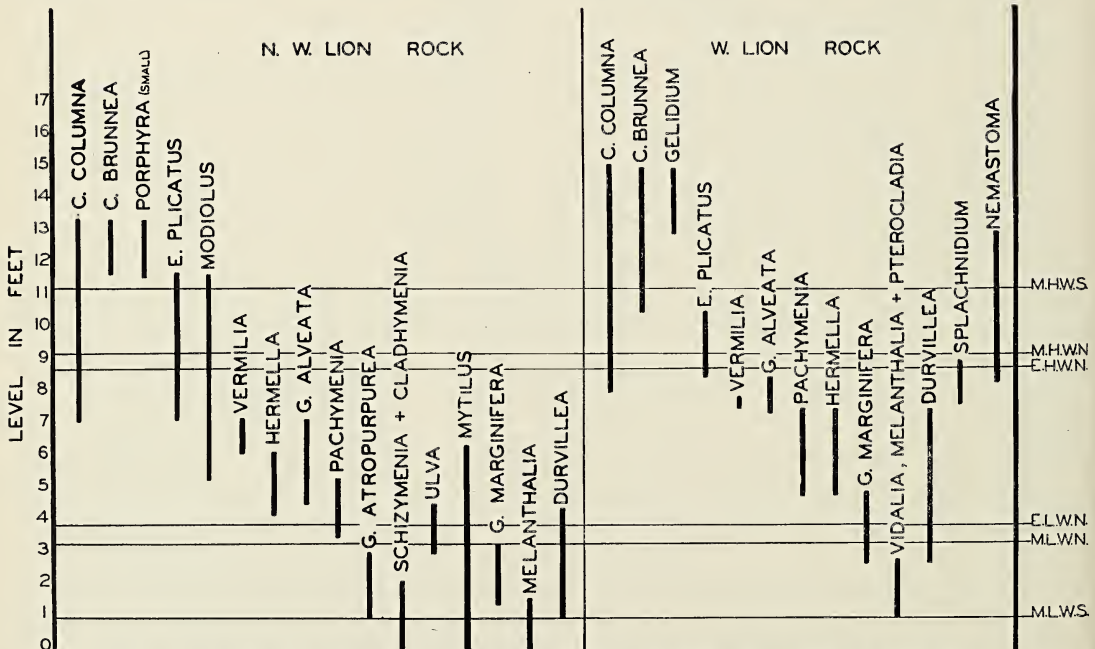


FIG. 10. Vertical distribution of species on the northwest and west of Lion Rock.



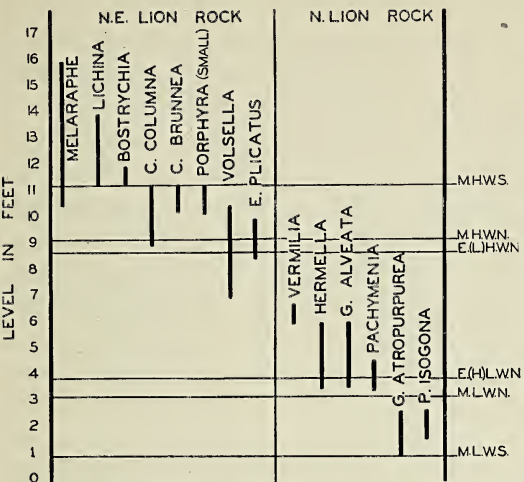


FIG. 11. Vertical distribution of species of the northeast and north of Lion Rock.

different adjustment. The chief guide used in making this adjustment was the level of the species in the most sheltered habitats. It

must, however, be emphasised that owing to the great difficulties involved this attempt at allowing for wave action can only be a first approximation. From a study of this diagram it may be concluded that the most marked critical levels (i.e., levels where a number of species reach their upper or lower limit) are as follows:

	Upper limits	Lower limits	Total
11 feet—M.H.W.S. . . . .	6	3	9
Between 8.5 and 9.5 feet . . . . .	3	3	6
4 feet—E.(H).L.W.N. . . . .	5	2	7
3 feet—M.L.W.N. . . . .	5	1	6
2.3 feet . . . . .	4	3	7
1.4 feet—M.L.W.S. . . . .	5	4	9

It will be seen that there are nine upper or lower limits between 11 feet and M.H.W.S. so that this, together with 1.4 feet, is one of the more distinctive levels. Reference to Fig-

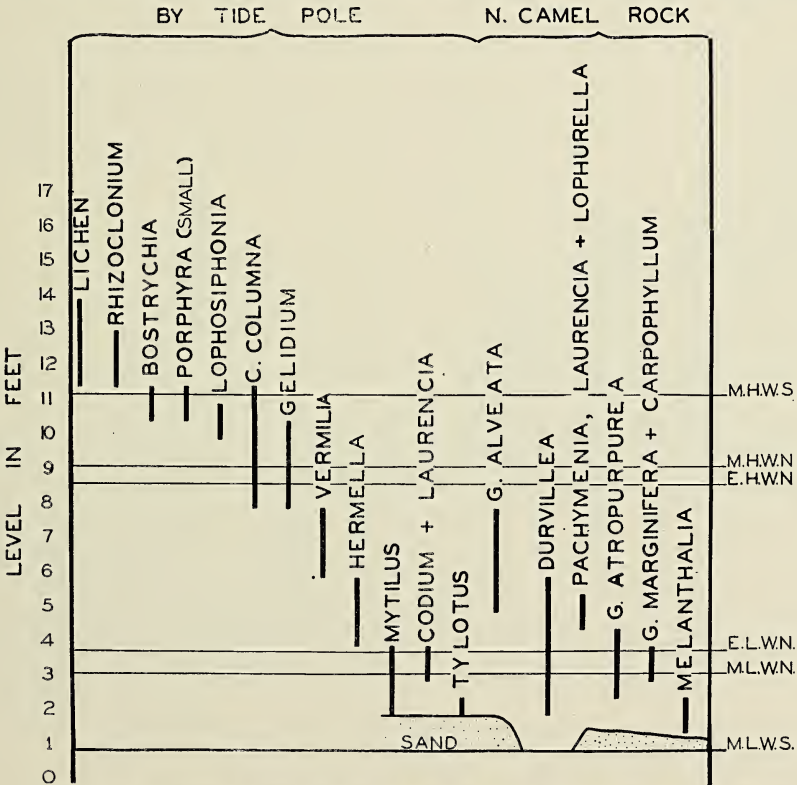


FIG. 12. Vertical distribution of species by the tide pole and on the north of Camel Rock.

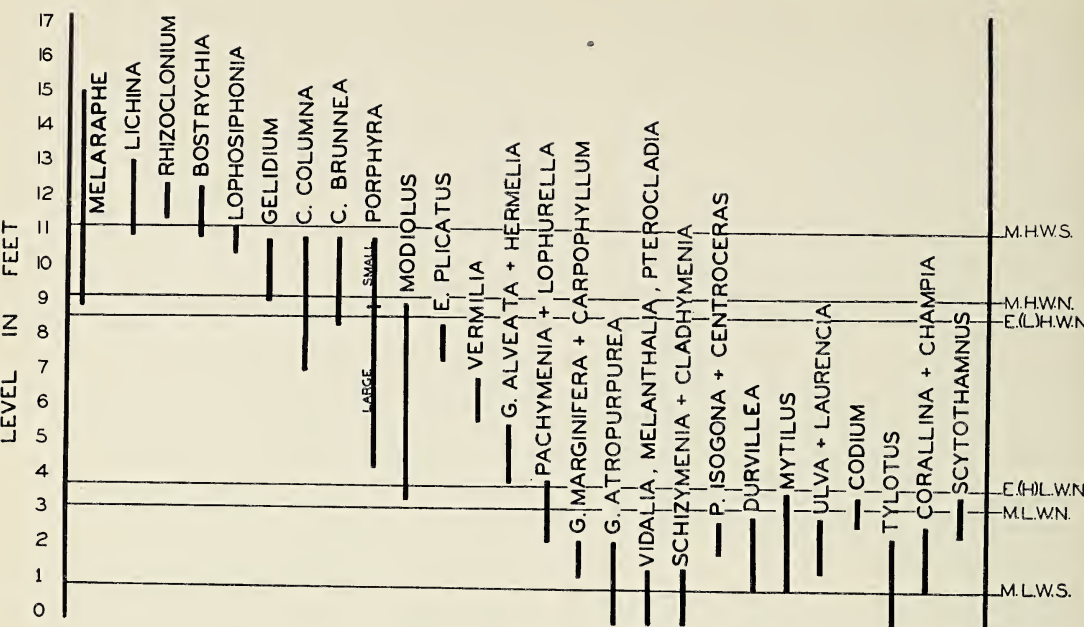


FIG. 13. Generalized vertical range of upper species at Piha after allowance has been made for the effect of wave action.

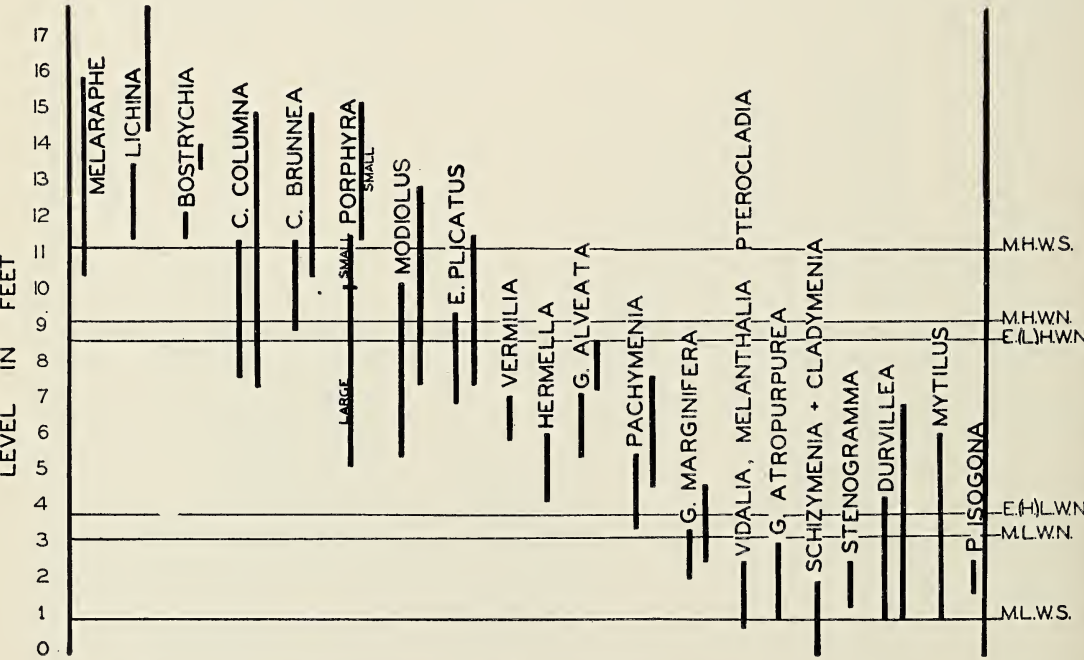


FIG. 14. Vertical distribution of dominant species at Piha generalized in positions of moderate shelter and exposure.



ures 5 and 6 will show that there is a change in total hours of exposure and also in total continuous exposure at this level.

The changes in total exposure and total continuous air exposure would seem to be the causal factors determining the six species with limits around  $\pm 9$  feet. The species limits at E.(H).L.W.N. are very clearly defined and include those of three species important ecologically, e.g., *Pachymenia himantophora*, *Gigartina alveata*, and *Mytilus canaliculus*. Probably causal agents at this level are the changes in the total amount of air exposure and continuous submergence.

At M.L.W.N. *Durvillea* is the most important species ecologically and there are changes in the total amount of continuous submergence, the maximum period of continuous submergence, and the number of tidal submergences. At 2.3 feet the causal factors probably include total amount of continuous submergence and the total number of submergences. At M.L.W.S. the principal tidal factor appears to be changes in total air exposure, though at this level, and with the number of species involved, competition may be severe.

#### SUMMARY

A general account is given of the intertidal zonation at Piha on the west coast just north of Auckland. Eleven major biological communities are recognised, together with a few local or seasonal communities.

A levelling survey of the more important species was carried out, and after correlating the tides at Piha with those at Auckland, the principal tidal phenomena were worked out from actual tide charts. In most areas exposure to wave action elevated the limits of certain species, especially those higher up on the shore. If allowance is made for this ele-

vation it is suggested that there are six critical levels at Piha; these are mean high water spring tides, about  $\pm 9$  feet, extreme (highest) low water mark neap tides, mean low water neap tides,  $\pm 2.3$  feet, and mean low water spring tides.

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# Metamorphosis of the "Non-aquatic Frog" of the Palau Islands, Western Carolines

KENJI ATODA<sup>1</sup>

## INTRODUCTION

THE FROGS in the Palau Islands seldom, if ever, leave their refuges during the daytime, but after sunset they are found easily in weedy places. There are two types of frogs, the large and the small, of which the larger is the female and the smaller the male. The male has strong jumping powers. Neither type has any webs between toes or fingers.

The adult frogs are well known to the Palau natives, who call them "gedegedug," "hedehedh," or "dechedeche," but it is interesting to know that no one has seen their tadpoles. I made a search for the tadpoles in some pools and ponds, but without success, and the question soon arose as to where and how these frogs pass through their larval stages. During my long stay in the Palau Tropical Biological Station on Koror Island, I was fortunate several times in discovering the spawning place of the frogs, and was thus given the opportunity to study their metamorphosis.

Here I wish to express my thanks to Professor Shinkishi Hatai, then Director of the Palau Tropical Biological Station, for his kind guidance throughout the observations.

## METAMORPHOSIS

The eggs collected from the natural spawning place were placed in a petri dish, the bottom of which was covered with a wet filter paper to maintain a humidity of about 100 per cent. The room temperature ranged from 25.1° to 31.0° C. throughout the period of observation.

The observations were made on one hatch, of which the youngest larva is shown in Figure 1*a*. The egg is covered with a rather tough gelatinous membrane and just after spawning it measures about 6 mm. in diameter. A large mass of yellowish-white yolk is attached to the abdomen of the larva. The three parts of the body—head, trunk, and tail—are distinguishable. The central part of the head is somewhat hollow, and rudimentary eyes appear on both sides. The mouth is a shallow invagination not yet open. The end of the tail is bent toward the abdomen. Each pair of limbs appears as rounded and protuberant swellings, the hind limbs being slightly larger than the forelimbs. Fine blood vessels run along the forelimbs, then toward the abdomen and finally branch into networks. The melanophores are not yet visible.

On the second day (Fig. 1*b*), a pair of well-developed eyes appears and the mouth opens, the tail becomes much longer, and the vascular system is conspicuously developed. The melanophores appear scattered over the head and trunk.

On the fourth day (Fig. 1*c*), the mouth is wide open and a pair of external nares is seen on its upper part. Numerous blood vessels are distributed over the abdominal region; the heart, which is perceptible through the skin, beats at an average rate of 120 times per minute (at a temperature of 30.8° C.).

On the seventh day (Fig. 1*d*, *e*), the yolk decreases and becomes flattened dorsoventrally. Five toes can be distinguished in the hind limbs but the forelimbs are hidden by the yolk mass. The melanophores increase in number on both the head and trunk.

On the tenth day (Figs. 1*f*; 2*a*), both the

<sup>1</sup>The Second Higher School, Sendai, Japan. Manuscript received July 20, 1949.



hind limbs and tail become more developed, and the latter reaches about 4 mm. in length. The body length, except for the tail, is about 5 mm.

On the fourteenth day (Fig. 2*b*), the egg reaches about 9.5 mm. in diameter. The egg seems to expand day by day as the larva grows in it. The skin of the abdomen, which begins to expand from about the seventh day of development, swells conspicuously and forms a pair of large, balloon-like sacs with a great number of blood vessels on the walls.

On the seventeenth day (Fig. 2*c, d, e*), the greater part of both tail and yolk are absorbed, and, except for the extreme expansion of the abdominal skin, the larva closely resembles an adult frog.

On the nineteenth day (Fig. 2*f*), nearly all of the yolk has been consumed and the tail is now rudimentary. When the egg is carefully removed from the vessel, the gelatinous membrane readily slips off and a miniature frog jumps free.

After a few more days all the larvae complete their metamorphosis, and as soon as they leave their eggs, the expanded abdominal skin contracts to adhere closely to the abdomen, showing the same appearance as in the adult frog. These young frogs measure about 6 mm. in length from the tip of snout to the anus.

#### ADULT FROG

Some of the external features of the male and female frogs are shown in Figure 3*a-e*.

Both types of frogs are dark brown but the male is the darker. The inside of the thighs is yellowish-red. In some frogs a fine line arises from the tip of the rostral and extends over the ridge of the back to the toe.

The tip of the rostral is somewhat rounded and the outer nostrils open close to its extremity. The distance between the rostrum and the point where the upper and lower jaws unite is slightly longer than the rostrum re-

gion. The distance between the extremity of the rostrum to the joint of each jaw is approximately equal to the width of head. The pupil is ellipsoid. The circular tympanum is conspicuous. Its diameter is about one and a half times the length between the hind margin of the eye and the fore margin of the tympanum, and is slightly shorter than the distance between each outer nostril. Close to the upper margin of the tympanum there is a narrow skin fold.

In the buccal cavity a pair of internal nostrils, a pair of triangular vomerine tooth plates, and a tongue are found. The tip of the tongue is bifurcated. The two types of frogs have tongues of different shapes; that of the large (female) frog is slenderer than that of the small (male) frog, and the distance between each small process is less in the large frog than in the small frog. There are minute teeth in the upper jaw but not in the lower jaw. The vocal sac is not very evident.

Some skin folds are scattered over the dorsal part of the trunk. Of the fingers of the forelimb, the third is longest, then the first is next longest; the other two fingers are nearly equal in length. Of the toes of the hind limb, the fourth is much more prominent than the others, and the first is shortest. The webs are completely degenerated. Many rounded protuberances of skin are found on the insides of the fingers, toes, palm, and metatarsus. The tips of both fingers and toes are rounded. The length from the base of the tibia to the tip of the longest toe is two and a half times that from the base of the arm to the tip of the longest finger, and is 1.6 times the length from the tip of the rostrum to the anus.

#### DISCUSSION

The eggs upon which the observations were made were collected in the months of May, October, and December. They were

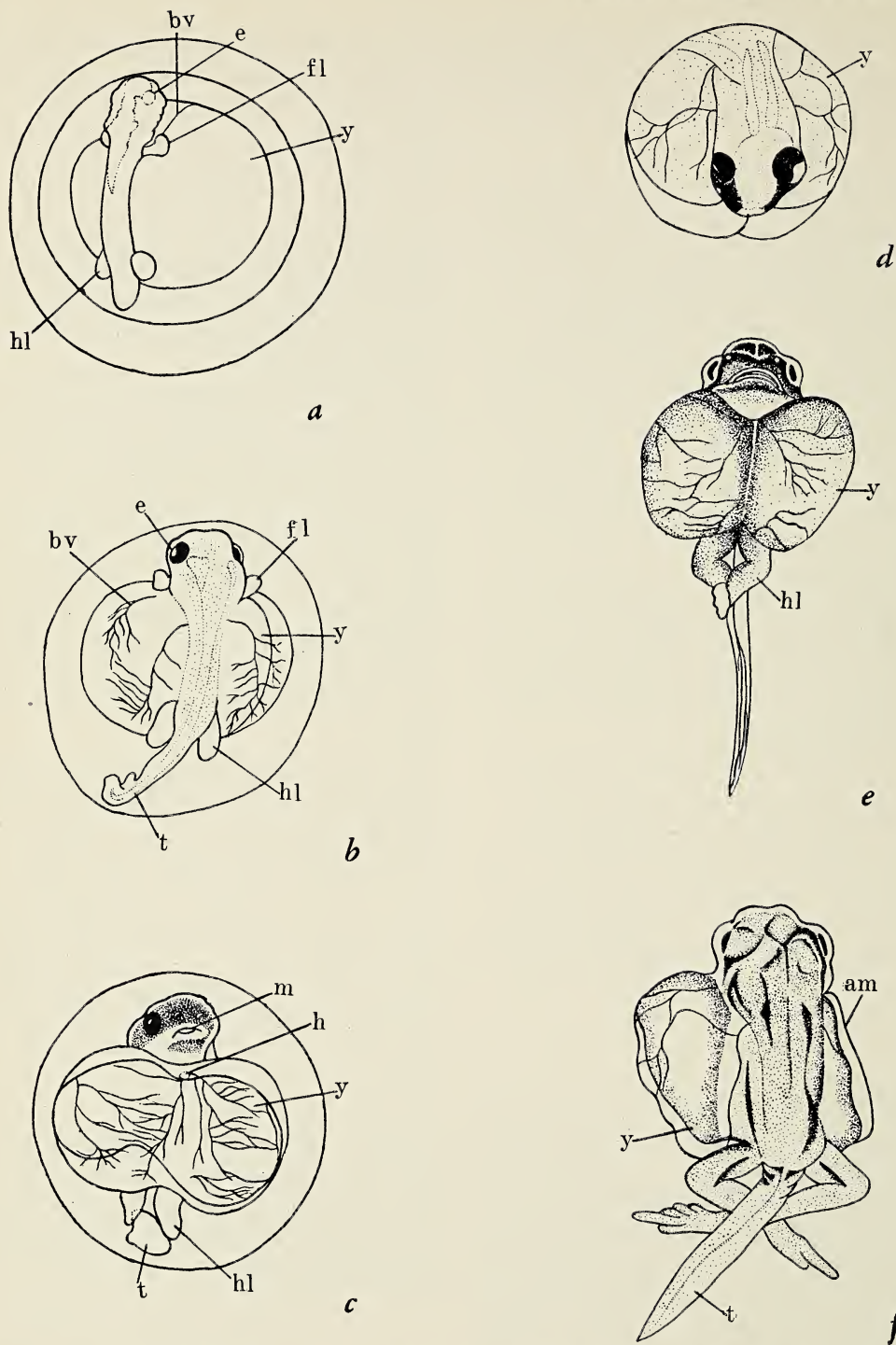


FIG. 1. Progressive stages of metamorphosis of the frog from the Palau Islands,  $\times 7$ . *a*, Dorsal view of the youngest larva (the outer gelatinous egg membrane is omitted); *b*, 2 days later, dorsal view (only the innermost egg membrane is drawn); *c*, 4 days later, ventral view; *d*, 7 days later (all membranes are removed from the egg), frontal view; *e*, same as *d*, ventral view; *f*, 10 days later, dorsal view. (am, Abdominal membrane; bv, blood vessel; e, eye; fl, forelimb; h, heart; hl, hind limb; m, mouth; t, tail.)



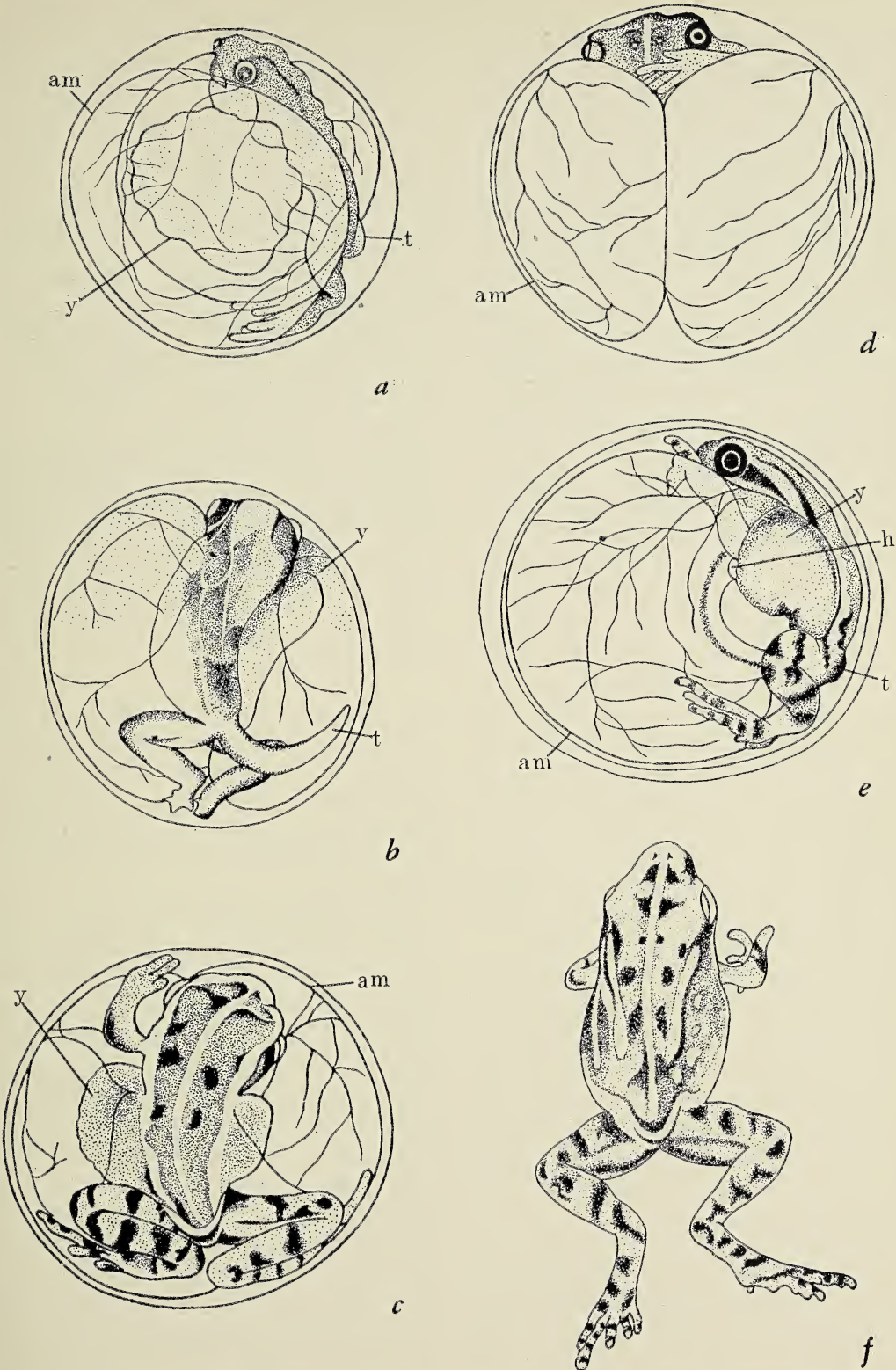


FIG. 2. Further stages in metamorphosis of the frog,  $\times 7$ . *a*, Same as 1*f*, lateral view, only the innermost egg membrane is drawn; *b*, 14 days later, dorsal view; *c*, 17 days later, dorsal view; *d*, same as *c*, lateral view; *e*, same as *c*, ventral view; *f*, 19 days later, egg membranes removed, dorsal view.

spawned in a weedy place on the ground. The number of eggs in one hatch was usually about 30. At the time of each collection it was noticed that a considerable number of eggs with large yellow yolks could be seen through the skin in the abdomens of large frogs. These observations lead to the conclusion that the frogs have no definite spawning time, but spawn every month throughout the year.

Metamorphosis is completed so rapidly that the first stage observed was probably close to the earliest stage. Apparently, the time required to complete the metamorphosis is about 3 weeks.

The characteristic features of the metamorphosis of this frog are the extreme swelling of the abdominal skin and the absence of both external gills and gill clefts. The larva does not pass a free-swimming stage in water; therefore external gills for respiration are unnecessary. The larva grows rapidly within the egg, and metabolism takes place actively. The expansion of abdominal skin or the increase of body surface and the abundant blood vessels in the skin may be helpful in increasing respiration through the skin. In addition to these characteristics, the larva depends wholly upon the yolk for nutriment throughout metamorphosis, and its yolk is large, like that of a fish egg. Observations on the cleavage of the egg were not made.

Hitherto only two species of frogs have been known to exhibit behavior more or less similar to that of the Palau frog: *Hylodes* (= *Eleutherodactylus*) *martinicensis* (Peters 1876; Lynn 1940) and *Rana opisthodon* (Boulenger 1886). Both of them undergo their whole metamorphosis within their eggs, and their embryos possess neither gills nor gill openings.

*Hylodes martinicensis* lays its eggs on a broad leaf of a plant, and the eggs are then glued to the leaf. The egg measures 4–5 mm. in diameter. The metamorphosis is completed during 21 days, approximately the

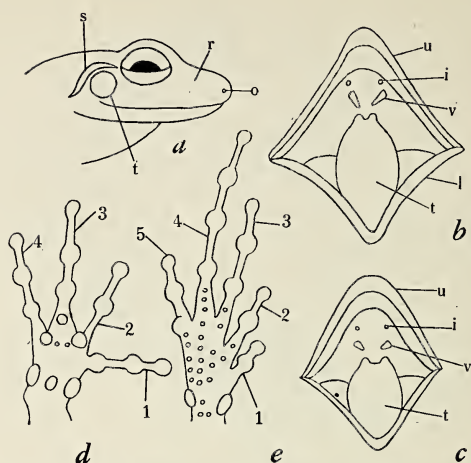


FIG. 3. Some external features of the adult frog. *a*, Lateral view of the head (approx.  $\times 1.6$ ; o, outer nostril; r, rostrum; s, skin fold; t, tympanum); *b*, buccal cavity of the large frog; *c*, same of the small frog (*b* and *c*, approx.  $\times 2$ ; i, internal nostril; l, lower jaw; t, tongue; v, vomere tooth plate; u, upper jaw); *d*, palm and fingers (approx.  $\times 2.6$ ; 1, 2, etc., the first, second, etc., fingers); *e*, metatarsus and toes (approx.  $\times 2.6$ ; 1, 2, etc., the first, second, etc., toes).

same time as was observed for the Palau frog. Its most noteworthy characteristic is the development of a large well-vascularized tail, the function of which is to serve as a respiratory organ, just as the extreme expansion of the abdominal skin of the Palau frog does for it.

*Rana opisthodon* deposits its eggs in moist crevices of rock close to water. Its egg measures 6–10 mm. in diameter. Its embryo develops without any evidence of a tail, and has as breathing organs several regular transverse folds on each side of the abdomen which function in a manner quite similar to *Hylodes*' tail. Thus the Palau frog is entirely different from these two species.

At present it seems that the data are not sufficient to determine the genus to which the Palau frog belongs. Although both hand and foot well resemble those of *Hylodes*, the other general features rather resemble those of the Ranidae, and the frog probably is a new species of *Rana*. The two types of frogs



found, the small and the large, seem to indicate the occurrence of sexual dimorphism in the species.

#### SUMMARY

1. The frog described in this article is commonly found in the Palau Islands. There are two types, large and small, apparently an effect of sexual dimorphism. Neither type possesses webs between toes or fingers. This frog is probably a new species of *Rana*.

2. The number of eggs in one hatch is about 30 and they are spawned on the ground in weedy or bushy places. Metamorphosis is completed in the egg, and the frogs do not experience the free-swimming stage of a tadpole. About 3 weeks are required for complete metamorphosis.

3. During metamorphosis neither external gills nor gill clefts appear, but the abdominal skin expands to an extreme degree.

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# On the Identity of *Spongocladia* and *Cladophoropsis*<sup>1</sup>

GEORGE F. PAPENFUSS<sup>2</sup>

IN THEIR TREATMENTS of the green algae in Engler and Prantl's "Die Natürlichen Pflanzenfamilien," Wille (1911: 119) and Printz (1927: 282) consider *Spongocladia* Areschoug (1853) as a genus of questionable merit. This belief was founded upon the observation of Weber-van Bosse (1890) that examples of *Struvea delicatula* which lived in association with the sponge *Halichondria* bore a great resemblance to *Spongocladia vaucheriaeformis*, the type species of the genus *Spongocladia*.

However, in a later work, Weber-van Bosse (1913: 86) not only maintained *Spongocladia* but emphasized that she had not demonstrated that *S. vaucheriaeformis* actually was a form of *Struvea delicatula* living in association with a sponge, and that there consequently was no justification for the statement of Wille (*loc. cit.*): "Nachdem es von A. Weber v. Bosse nachgewiesen worden ist, dass die typische Art: *S. vaucheriaeformis* Aresch. nur eine durch Symbiose mit einer Spongie (*Halichondria*) umgebildete *Struvea*-Art darstelle, muss auch die Stellung der 2 übrigen Arten: *Spongocladia dichotoma* (Zanard.) Murr. et Boodle, sowie *S. neocaledonica* Grun. als sehr zweifelhaft angesehen werden."

Even though there probably is no particularly close relationship between *Spongocladia* and *Struvea* Sonder (1845), both of which belong to the order Siphonocladales, but to the families Siphonocladaceae and Boodleaceae, respectively, I have on a number of oc-

casions been struck by the agreement in the published descriptions and illustrations of *Spongocladia* and *Cladophoropsis* Børgesen (1905), both members of the family Siphonocladaceae. The purpose of the present article is to assemble the published facts and to record my own observations in support of the contention that these two genera of essentially tropical and subtropical marine algae actually are identical, a conclusion which Børgesen (1948) has also reached. Finally, *Cladophoropsis*, which is the better known genus, is proposed for conservation against *Spongocladia*.

The genus *Spongocladia* was erected by J. E. Areschoug in 1853 upon a new species, *S. vaucheriaeformis*, which he received from Mauritius. The plants grew upon encrusting corallines, forming a horizontal spongioid mass, from which issued erect, more or less dichotomously divided, spongioid growths. Both the horizontal and the erect portions of the thallus were composed of irregularly branched, septate, uniseriate filaments and, as shown in Areschoug's figure 3, the branches of the filaments lacked a cross wall at the base. Reproduction appeared to be by swarmers, many of which germinated within the cells in which they were produced. The thallus contained an abundance of sponge spicules, especially at the terminal ends of the erect portions.

Thirty years later the known geographic distribution of *Spongocladia vaucheriaeformis* was extended to Singapore by Hauck (1884). His study of the plant led him to the significant conclusion that systematically it belonged in the immediate vicinity of *Siphonocladus*, a genus which had been founded a few years previously by Schmitz (1879) to

<sup>1</sup>This study was made during the tenure of a Guggenheim Fellowship.

<sup>2</sup>Department of Botany, University of California, Berkeley, California. Manuscript received February 1, 1950.



accommodate two species, one of which was subsequently removed to *Cladophoropsis* by Børgesen (1905).

In 1888 Murray and Boodle published an account of the genus *Spongocladia* based upon a study of material of *S. vaucheriaeformis* from Mauritius and New Guinea and of two additional species from the south Pacific. They pointed out for the first time that the genus *Spongodendron* of Zanardini (1878), which was based upon two species (*S. crassum* Zanard. and *S. dichotomum* Zanard.) from New Guinea, was indistinguishable from *Spongocladia*. *Spongodendron crassum* was found to be identical with *Spongocladia vaucheriaeformis* whereas *Spongodendron dichotomum* could be maintained as a distinct species under the binomial *Spongocladia dichotoma* (Zanard.) Murray et Boodle. In addition, Murray and Boodle gave a brief account and the formal diagnosis of a new species from New Caledonia, *Spongocladia neocaledonica* Grunow, which differed from the others in having a compact thallus.

Up to the present no additional species of *Spongocladia* appear to have been described, but our knowledge of the genus has been enlarged in certain respects and the known geographical range of two of the species has been extended.

Heydrich (1894) reported *S. vaucheriaeformis* and *S. dichotoma* from the Ryukyu Islands, south of Japan. He was the first to bring attention to the fact that the thalli were not composed of a single plant but of a large number of individual *Cladophora*-like plants. In agreement with the observations of Zanardini and Murray and Boodle, he found that the filaments composing the thallus produced attachment organs, or tenaculæ, by means of which they anastomosed with near-by filaments, forming a kind of network.

Heydrich was also the first to give an account of the method of formation of the so-called aplanospores (or coniocysts, as they had been called by Zanardini). He regarded

*Spongocladia* as essentially a unicellular alga, which, like *Valonia*, formed aplanospores which produced daughter individuals that remained attached to the mother-plant. As we now know, the aplanospores of Heydrich were protoplasmic masses formed in consequence of segregative division, a characteristic feature of the order Siphonocladales. Like Hauck, Heydrich placed *Spongocladia* near *Siphonocladus*.

In 1913 Weber-van Bosse recorded *S. vaucheriaeformis* from Makassar and neighboring islands in the Dutch East Indies. She expressed the opinion that *Spongocladia* probably represented special forms of algae known otherwise by different names.

Okamura in 1916 recorded the occurrence of *S. vaucheriaeformis* at Ponape and Saipan in the Caroline and Marianas Islands, respectively. In a later work (1928), he confirmed the observation of Areschoug regarding the germination of spores (?) within the cells in which they were formed. He also saw and figured stages in their germination on the outside of filaments of the thallus. The germination of spores (?) within the reproductive structures was later observed by Yamada (1934) also. He appears to have been the first to have noted pores in the walls of the fertile cells, which suggests that the spores (?) are motile and that those which had been seen within the cells had merely failed to escape, as is so often true in the algae.

Although Okamura (1928) does not seem to have been fully aware of it, he clearly observed (see pl. 250, fig. 11) septation of the filaments by segregative division, thus confirming the observation (in the light of present knowledge) of Heydrich.

As far as I am aware, Dickie (1875), Jadin (1934), Lucas (1935), and Børgesen (1940, 1946, as well as 1948) are the only authors in addition to those already mentioned who have studied *Spongocladia*. Dickie, Jadin, and Børgesen included *S. vaucheriaeformis* in their lists of algae from Mauritius, whence

the species was first described, and Lucas reported it from Lord Howe Island.

In summary, then, a synthesis of the accumulated knowledge concerning the general morphology of *Spongocladia* reveals the following features as most characteristic of the genus:

1. The thallus is in the form of a prostrate, spongioid growth, which remains as a compact mass in *S. neocaledonica* or produces erect, branched, *Codium*-like processes in *S. vaucheriaeformis* and *S. dichotoma*.

2. The thallus is composed of intertwining, branched, septate filaments, with the cells arranged in a single series.

3. The branches of the filaments are not separated by a cross wall at the point of juncture with the parent filament.

4. Septation of the filaments is by segregative division.

5. The filaments form attachment organs, or tenaculæ, by means of which they anastomose with other filaments, forming a kind of network.

6. Reproduction is by swarmers which are produced in the unmodified cells of the filaments.

These characters, with the possible exception of the first one listed above, indicate that *Spongocladia* Areschoug (1853) is identical with *Cladophoropsis*, a genus which was segregated from *Siphonocladus* Schmitz (1879) by Børghesen in 1905. This conclusion is supported by my own observations (particularly in regard to the absence of a cross wall at the point of attachment of the branches to the parent filaments) upon a species of *Spongocladia* (seemingly *S. vaucheriaeformis*) from the Philippine Islands and by those of Børghesen (1946, 1948) upon *S. vaucheriaeformis* from Mauritius. The agreement in the general appearance of the filaments composing the thallus in *Spongocladia* and *Cladophoropsis* is shown in Figure 1a and b, respectively, which are reproductions of illustrations by Børghesen from material gathered

in the type regions of the type species of the two genera.

The observations of Børghesen in this connection are especially significant inasmuch as they were made, not only upon topotype material of the type species of *Spongocladia*, but by the author of *Cladophoropsis*. In 1946 (p. 17) he remarked: "According to my observations of the alga [*S. vaucheriaeformis*] it seems to me very like *Cladophoropsis*, for instance, *Cl. Zollingeri* . . ." and in 1948 (p. 24) he said, "the alga, being the biont of the sponge, is quite like that found in the formerly examined specimens, and thus in my opinion is a *Cladophoropsis*."

Seemingly, the only difference between *Spongocladia* and *Cladophoropsis* lies in the general habit of the two genera. In *Cladophoropsis* the thalli are in the form of cushions, turfs, or tufts whereas in two of the species of *Spongocladia* (*S. vaucheriaeformis* and *S. dichotoma*) the basal prostrate system ordinarily produces erect, *Codium*-like portions. However, these differences are not constant and appear to be of a specific rather than a generic nature. Support for this contention is furnished by two facts: (1) In *S. neocaledonica* the thallus is in the form of a compact, barely branched growth, somewhat comparable to that of *Cladophoropsis membranacea* (Børghesen, 1913: 43 and 47) and certain other species in which the thallus is in the form of dense cushions or turfs. (2) Even in *S. vaucheriaeformis* the thallus may at times, according to Børghesen (1948: 23), be in the form of an extensive prostrate mat, with the erect portions reduced to conical growths of only 2-3 cm. in height.

Since the time that Børghesen (1905) erected *Cladophoropsis*, and transferred to it seven species which had previously been placed in *Siphonocladus*, the genus has been found to be well represented in tropical and subtropical waters, and to contain a few species which are known only from temperate regions. A search through the literature re-



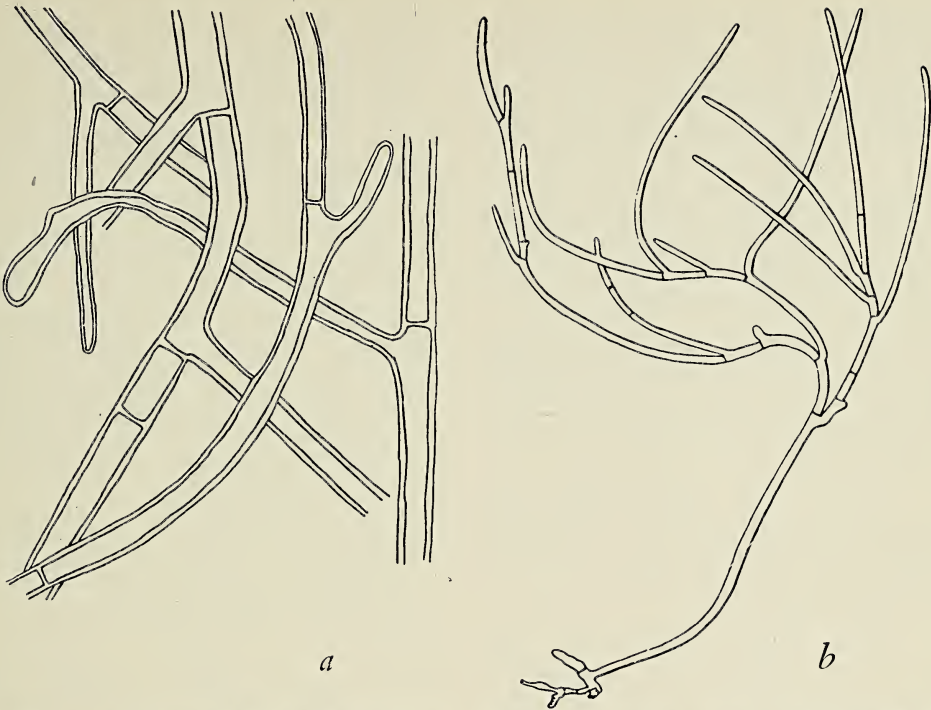


FIG. 1. *a*, *Spongiocladia vaucheriaeformis*: filaments from the upper part of the thallus of a plant from Mauritius.  $\times 45$ . *b*, *Cladophoropsis membranacea*: a part of the cushion-like thallus of a plant from the Virgin Islands. About  $\times 5$ . (From Børgesen, 1948 and 1905, respectively.)

veals that up to the present some 19 species have been accredited to *Cladophoropsis*. They are: *C. brachyartra* (Sved.) Børgesen (1905); *C. fallax* Schiffner (1933); *C. fasciculata* (Kjellm.) Børgesen (1905); *C. gracillima* Dawson (1950); *C. herpestica* (Mont.) Howe (1914), incl. *C. coriacea* Yendo (cf. Yamada, 1944); *C. howensis* Lucas (1935); *C. infestans* Setchell (1924); *C. limicola* Setchell (1924); *C. macromeres* Taylor (1928); *C. membranacea* (Ag.) Børgesen (1905); *C. modonensis* (Kütz.) Børgesen (1905); *C. pallida* Baardseth (1941); *C. peruviana* Howe (1914); *C. psyttaliensis* (Schm.) Børgesen (1905); *C. rigida* (Howe) Feldmann (1938); *C. robusta* Setchell et Gardner (1924); *C. sundanensis* Reinbold (1905); *C. voluticola* (Hariot) Børgesen (1905); and *C. Zollingeri* (Kütz.) Børgesen (1905).

Considering the wide recognition which *Cladophoropsis* has received in the course of

the past 45 years as contrasted with *Spongiocladia*, which has been referred to in a comparatively small number of publications, it would be advantageous to reject the latter name in favor of the former, and it is accordingly proposed that *Cladophoropsis* be considered for conservation.

CLADOPHOROPSIS Børgesen (Siphonocladaceae), K. Danske Vidensk. Selsk. Forhandl. 1905: 288, 1905.

versus

*Spongiocladia* J. E. Areschoug, Öfvers. K. Vetensk.-Akad. Förhandl. 10: 202, 1853.

Type species: *Cladophoropsis membranacea* (Ag.) Børgesen.

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# Luminous Organs of Fish Which Emit Light Indirectly

YATA HANEDA<sup>1</sup>

## INTRODUCTION

THERE ARE MANY REPORTS of luminous fishes, all of which, in earlier days, were taken from the deep seas. Luminous organs were found on the sides of the bodies, on the barbels, or on the antennae. In outward appearance these fishes were strangely shaped and feebly developed, with soft bones and loose muscles, and it was assumed that such unusual fishes belonged exclusively to the deep-sea fauna.

The material examined was invariably dead and damaged. It might have been newly caught, or else had been preserved in formalin or in alcohol for an indefinite period.

There seems to be very little record of observations on living material, and only the morphology of the organs of these fishes was studied. The organs were never really understood, and were mistaken for sensory organs, electric organs, or secondary eyes, or they were simply referred to as eye-like organs.

In the early days bacteriological knowledge, especially knowledge of luminous bacteria, was not far advanced, and fish which became luminous after death as a result of contamination by saprophytic luminous bacteria were mistaken for true luminous fishes.

Recent advances in the study of these interesting problems of luminosity have shown that luminous fishes are not confined to the deep-sea fauna, but may be found among the fauna of the shallow and coastal waters of the sea, and that luminosity may be caused by luminous bacteria. Moreover these studies have revealed that luminous bacteria play an important role in the production of light in

some fishes by entering certain ducts possessed by these fishes, and there settling down to a symbiotic existence. Within the duct they are cultured and utilized as a source of light, the fish undergoing some modifications to create an organization within itself to display the light. Such an association between a fish and luminous bacteria constitutes what is known as luminous symbiosis.

Most known luminous fishes are found in deep oceanic waters and have on the surface of their heads or bodies, or on their barbels, or on their antennae, curious arrangements of luminous organs of varied shapes, sizes, and arrangements. For example the luminous sharks have on the side of their bodies simple, small luminous dots which consist of groups of luminous skin organs. The genera *Stomias*, *Chauliodus*, and *Gonostomias* also possess numerous luminous dots in the underlying skin in addition to their regular series of luminous organs. A *Porichthys* species has rows of many small luminous organs which follow the direction of the multiple lateral lines. A *Pseudoscopelus* species has numerous minute luminous organs arranged in indefinite rows of a characteristic shape. The lantern fishes (Myctophidae) possess fewer luminous organs, but these are pearl-like and are arranged symmetrically in a series on each side of the fishes. In some species of *Lampanyctus*, luminous scales may be present above or below the tail base. Luminous patches or ducts occur on the head of *Diaphus* or on the body of *Lampanyctus* species. The Sternoptychidae and Stomiidae are characterized by highly developed luminous organs of a more complex structure, consisting of a luminous body, reflector, lens, and color fil-

<sup>1</sup>Tokyo Jikeikai Medical College, Tokyo, Japan.  
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ter. In addition to the serial luminous organs on the body there may be luminous organs on the jaws and near the eye. The more complex postocular organ of the Stomiidae is freely movable, and can be rolled inward when not required.

In the families Stomiidae and Malacosteidae there is a barbel which, in *Diplolychnus*, is luminous at the end. In many other species, however, it is not certain whether this barbel is luminous or not.

Deep-sea angler fishes have a luminous antenna. *Lamprotopus* has a closed loop of luminous tissue on each side of the body between the head and pelvic region, while in *Eurypharynx* and *Saccopharynx* there is a looped luminous organ which extends along each side of the dorsal fin as far as its posterior extremity, beginning either just behind the skull or just in front of the anterior extremity of the fin. There is a half-moon-shaped luminous organ which is freely movable and which can be rolled inside situated below the eye in *Anomalops*. *Photoblepharon* can shut off the luminous part of the organ by lowering a black membrane which functions like an eyelid. A species of *Doliichopteryx* has a luminous organ on the ball of the eye in front of the lens. *Monocentris japonicus* has a pair of luminous organs on the end of the jaws. Some species of the families Gadidae and Macrouridae possess a luminous organ ventrally\* in front of the anus.

All of these mentioned luminous organs are of the direct emission type. That is, their luminescence is emitted directly from the source (the luminous body) and remains more or less concentrated or focused at one point without much diffusion.

Some luminous fishes show no outward peculiarities in structure or appearance and resemble ordinary non-luminous fish. This is because the luminous body lies inside the fish and cannot be seen. Before its light can be seen it must first be directed to a reflecting

surface within the body. The light is reflected to pass through a considerable lateroventral translucent area of lenticular muscles where it appears as a diffused bluish glow. This diffusion may be compared with the effect which a frosted or "opal" bulb of an electric lamp has in screening the glare of the incandescent filament and reducing it to a diffused glow. As far as is known this indirect emission type is confined to *Acropoma* and the Leionathidae.

These fishes differ from other luminous fish in possessing unusually large luminous areas. In fact they utilize half the muscles of their complicated body structure for this purpose. Recently Kato (1947) discovered that *Apogon marginatus* Döderlein, belonging to the family Apogonidae, also possesses this same type of luminous organ.

I have made a study of luminous fishes since 1933, and have collected considerable material in Japan and in more southerly regions. Subsequent to 1937 I worked at the Palao Tropical Biological Station on several occasions during which I took the opportunity to visit the Philippine Islands, North Borneo, New Guinea, Celebes, Java, Sumatra, and Malay, where I collected many specimens of living luminous tropical fishes and observed their luminosity.

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#### LUMINESCENCE IN *Acropoma japonicum* *Material*

*Acropoma* is a genus of fishes of the family

Acropomidae found in the Sea of Japan and the Philippine Sea. Two species are known: *Acropoma japonicum* Günther, and *Acropoma philippinense* Günther. *Acropoma philippinense* was found near the Philippine Islands by the "Challenger" at a depth of 82 to 102 fathoms. *Acropoma japonicum* is known as "Hotaru-jako" in Japan, and is considered there to be a single species.

I have examined a large number of these "Hotaru-jako" in a fresh condition and believe that there are two species (Haneda, 1939) but in the absence of confirmation of this belief by an ichthyologist, I refer to them as Type I and Type II (Figs. 1 and 2). They both occur in the southern Japan Sea as a mid-water dweller in a depth ranging from about 80 fms. to 200 fms. They are beautifully rose colored and attain a length 200 mm.

If these two types are examined in detail many differences are found, not only between their external characters, but also between their luminous organs. For example:

Type I is colored pale red dorsally, and whitish ventrally.

Type II is a beautiful purple-red dorsally, and ventrally is light purplish-red.

Both possess many chromatophores on the ventral sides but Type II possesses the greater number.

The scales of Type I are firmly fixed in the body, while in Type II they are extremely deciduous; for this reason it is very difficult to obtain in the public fish markets specimens of Type II with scales attached.

The anus in Type I is situated approximately under the third spiny ray of the dorsal fin, but in Type II it is situated below the hindmost edge of the end of the dorsal fin.

The anus in Type I is white and in Type II it is strongly black pigmented.

Type I is furnished with a pair of canine teeth which Type II lacks.

Type I occurs in water of about 80 fms. in depth, while Type II occurs in waters more than 100 fms. deep. They are very seldom taken together by trawling vessels.

The greatest difference, however, lies in the size of the U-shaped internal luminous gland. That of Type I is short, with the ends directed posteriorly; while that of Type II is much longer, with the free ends directed anteriorly.

These differences, I suggest, justify the creation of a second species, but I prefer to call the two kinds of fish Type I and Type II. I have examined many specimens of both types, as well as males and females of each type. The gonads of Type I are full in October and those of Type II from December to February. All ichthyologists have considered them to be the same species, *A. japonicum*, and Type II only a variety of Type I, but in my opinion each is a distinct species.

During the winter season they are caught by trawlers in the Gulf of Tosa off Shikoku Island, Japan, in depths varying from 80 to 200 fathoms, and there is no difficulty in obtaining specimens in the Mimase fish market near the city of Kōchi, Shikoku Island. During each of the winters of 1934 to 1940 I obtained many specimens in this fish market. In Mimase and Urado near Kōchi, they are called Hotaru-jako, meaning "the small firefly fish," or Kigane-jako, and the fishermen who catch them during the night are aware of the luminosity in their ventral regions, as are most of the ichthyologists, who state that the luminosity is due to the numerous small black points on the ventral surface of the body. These they consider are skin organs similar to those of the luminous sharks, but they do not describe their structure.

It was not until I had dissected many fresh specimens that I discovered the peculiar luminous organs established in them and perceived that the small black points which had



been believed to be small luminous organs were nothing more than chromatophores.

The luminous organs consist of the following five components: a U-shaped luminous filiform body; an external opening of the canal of the luminous body; a reflector; a series of lenses; and a means of controlling the display of luminescence.

*Luminous Organ of A. japonicum Type I*  
(Fig. 1)

*Luminous Gland*—The luminous gland is

a whitish-yellow U-shaped filiform body, like a U-tube, lying flat and embedded in the muscles of the pectoral and ventral regions. Each "limb" of the tube is sealed at its end. The bend of the tube lies nearer the head than the closed ends of the "limbs" or filaments. This bent filament has an outer layer of longitudinally arranged fibers, an inner layer of circularly arranged fibers, and an innermost folded glandular epithelium, which surrounds a hollow duct or cavity. It is pierced on the

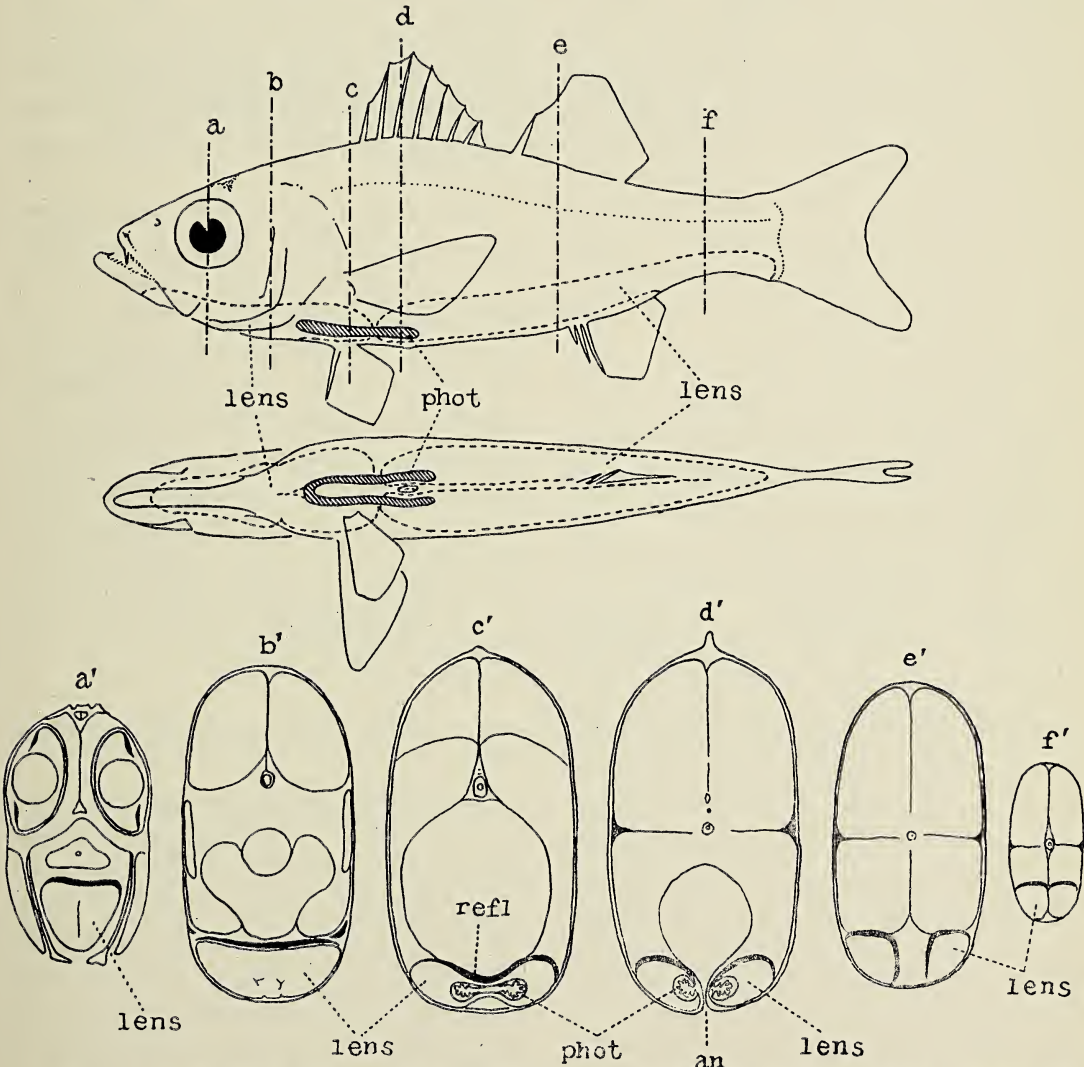


FIG. 1. Diagrammatic figure of the luminous organ of *Acropoma japonicum* Type I: phot, luminous gland; lens, lens; refl, reflector; a', b', c', d', e', f'—transverse sections at a, b, c, d, e, and f.

inner faces of the limbs by numerous capillary ducts which enter a larger central canal lying between the inner faces of the limbs of the U-tube. This canal is bounded dorsally and ventrally by concave membranes and has only one opening, which is at the anus. The whole luminous gland from a specimen 145 mm. long measured 14 mm., and from a fish 110 mm. measured 13 mm.

*External Opening*—In the gland, bacteria occur in the film of material which lies on the inner surface of the epithelial cells. These bacteria are present in clusters or else are attached to the surface of the gland cells. They pass from there into the duct or cavity of the U-shaped gland via the gland ducts. Here they remain until they pass through one of the numerous capillaries or pores into the larger central canal which opens in front of the anus. This is the only external opening of this canal. A luminous organ with an opening of this type is known as an open type of luminous organ.

*Reflector*—The reflector is a white, opalescent, opaque membrane lying above the luminous duct and extending from the isthmus to the end of the caudal peduncle. It lies rather low ventrally, and separates the lower ventral or keel muscles from the upper lateral and dorsal muscles. It passes below the pericardial and perivisceral cavities; under the latter it is depressed and forced downward into a concavity. Elsewhere it lies flat.

*Lens Structure*—The lower ventral or keel muscles below this membrane are lenticular and modified to transmit light. They are translucent but cloudy. They lie longitudinally and in pairs, i.e., one pair on each side. The first pair extends, one on each side, from the isthmus to the anus. The second pair lies, one on each side, from the anus to the end of the caudal peduncle. As they lie extended they may touch each other in places, but where they are not in contact they are separated by non-translucent muscle of ordinary structure. The luminous gland passes through

these muscles, and each limb passes backward, one on each side, the bend being in the anterior part of the body of the fish, and the closed ends of the limbs being directed backward in the direction of the anus. When I made complete cross sections of fresh fish, I noticed that where I had cut through the limbs of the organ, the luminosity was brilliant; it was only moderate and diffused in the muscles which were cut. The light was screened by the reflecting membrane above, but was reflected downward and laterally through the skin of the fish. Where I cut a cross section of a fish without cutting the limbs of the luminous gland, the muscles surrounding the limbs appeared to be luminous, suggesting that the muscles themselves were luminescent.

*Light Control Mechanism*—This luminous organ has in itself no regulating mechanism for controlling the display of light. On the other hand, the ventral area and lower lateral area below the reflecting membrane are furnished with a great number of chromatophores in the surface of the skin. Above the membrane this particular kind of chromatophore disappears and is replaced by another kind. The former are the chromatophores which at one time were considered to be the actual luminous organs, but by their contraction and expansion they probably control the amount of light emitted.

*Luminous Organs of A. japonicum Type II* (Fig. 2)

The luminous gland is situated in the ventral muscle and is long compared with that of Type I. It extends from the isthmus to about the 5th ray of the anal fin, where it bends with a short loop on each side of the fin. These loops are directed obliquely downward, and continue in a reverse direction for a short distance where the bend is continued to the center. In this way the two limbs form a kind of hooked loop, such as would be



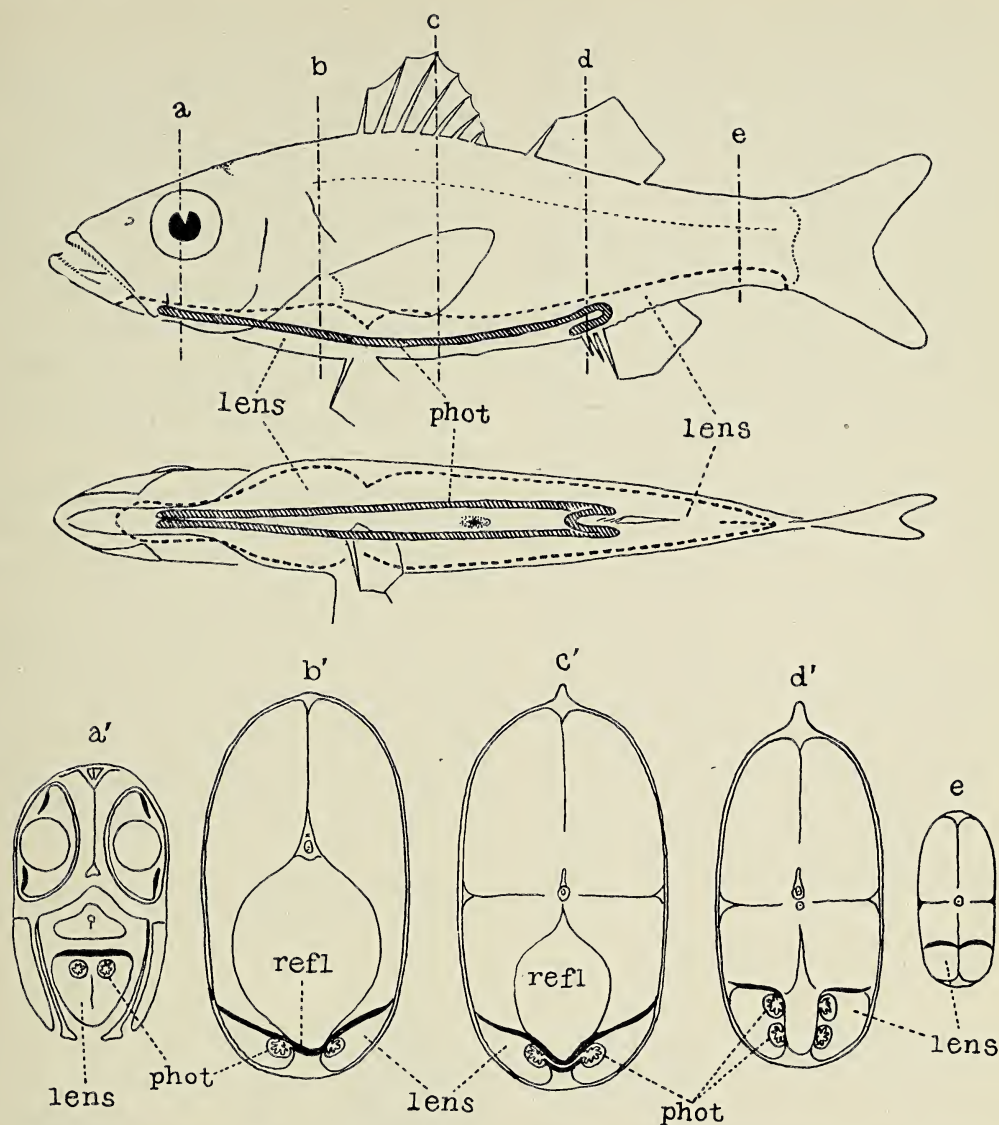


FIG. 2. Diagrammatic figure of the luminous organ of *Acropoma japonicum* Type II: phot, luminous gland; lens, lens; refl, reflector; a', b', c', d', e—transverse sections at a, b, c, d, and e.

made if the closed end of a hairpin were bent over to form a hook.

The free ends of each limb of this organ lie in the isthmus, and the arrangement is a complete reversal of that found in Type I. The gland is reddish-yellow when fresh. Structurally it is similar to that described for the fish of Type I.

The central canal between the inner loops continues beyond the anus and opens into

the cloaca through an opening which completely encircles it.

The muscles which form the lenses are comparatively poor as lenses when compared with those of the Type I fish, but are similar in other respects and equally translucent. The chromatophores are extremely numerous in the ventral region, and there are many more of them than in the fish of Type I.

These two types of luminous organs of

*Acropoma japonicum* are peculiar organs of a new type. The luminous glands are situated in the muscles, and they may be considered as an indirect or reflecting type of luminous organ functioning by reflected light.

#### *Remarks on the Luminescence*

Since the luminous gland is not visible on the surface of the body, both types of fish, externally and in daylight, have the appearance of ordinary non-luminous fish.

In the dark, however, e.g., when caught alive in a net at night, the ventral area is brilliantly illuminated. The luminosity is continuous, never disappearing completely, but may be dimmed by means of the chromatophores.

When the fish are recently dead the luminosity persists in both types, but gradually becomes dim. One or two days after death the muscles become opaque and are no longer translucent, and then the luminosity is extremely dim. If, however, after this period, the luminous glands are removed it will be seen that their luminosity persists as brilliantly as before and can even be seen in daylight by shading the glands in the cupped hands.

#### *Remarks on the Substance in the Luminous Glands*

To examine the substance in the glands, I made emulsions of it in distilled water, in 0.5, 2, 3, and 4 per cent NaCl solutions, and in sea water. These emulsions were kept at 18°–23° C. and were examined in the dark.

The sea water emulsion was the most luminous; next in order were the 3 per cent NaCl, the 4 per cent NaCl, the 2 per cent NaCl (which was rather weak), and the 0.5 per cent NaCl (which was extremely weak). The distilled water emulsion was not luminous.

The temperature of the sea water emulsion was lowered to 0° C., at which temperature it showed only a weak luminescence, but recovered its strength when warmed to 18° to 23° C., within which range it was strongest. At temperatures above 30° C. the luminosity diminished until at 45° C. it was no longer visible. When cooled it regained its luminescence, but it was lost again below 0° C.; however, luminescence was again recovered when the emulsion was warmed.

#### *The Luminous Bacteria*

When the emulsion of the gland was ex-

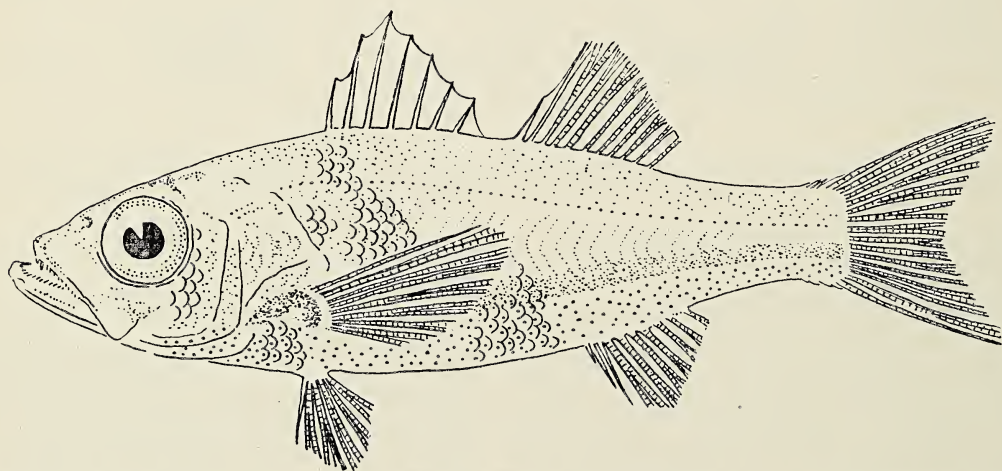


FIG. 3. *Acropoma japonicum* Günther Type I. The luminous organ is not seen externally, so that the fish looks like a common non-luminous one, but the lower part of the fish body is a lightning-like bluish-white color.



amed microscopically a large number of bacteria and some duct cell fragments could be seen. In the latter could be seen what were apparently bacteria since they stained well with Ziehl's solution and were Gram negative. Bacteria which had been taken from the luminous gland and cultured in media were tested for luminescence in the same solution as were the emulsions.

One hundred different strains of the luminous bacteria were obtained by the usual bacteriological techniques from 100 of each of the two different types of *Acropoma japonicum*. The cultures of bacteria taken from each of the types of fish showed some differences. On the basis of preliminary tests it appears that they represent two heretofore unknown species of bacteria which will be discussed at length in a separate paper. I tested the agglutination reactions of representative strains of these two new kinds of bacteria, and they showed a strain specificity similar to that of other symbiotic luminous bacteria (Kishitani 1930, 1932; Yasaki and Haneda, 1936).

#### LUMINESCENCE IN THE FAMILY LEIOGNATHIDAE

##### *Material*

The fishes belonging to the family Leionathidae are true shallow-water forms, and are abundant in the southern Sea of Japan and in tropical seas. When I published my account of the luminescence of these fishes in 1940 I was not aware that their luminescence was already known, and it was only by chance that I found, in 1943, a reference to the work of J. W. Harmes in *Biological Abstracts* in the Raffles Museum Library. It is an abstract of a paper which appeared in 1928, entitled "Bau und Entwicklung eines eigenartigen Leuchtorganen bei *Equula spec.*" Unfortunately I have not yet been able to see the full account of this discovery. However, while working independently on lumi-

nous organisms of the South Sea Islands at the Palao Tropical Biological Station, I discovered that *Gazza minuta* and several other species in this family are also luminescent when alive. The Leionathidae living in shallow waters are not provided with externally visible luminous organs and superficially they resemble ordinary non-luminous fishes. For this reason their luminosity was unexpected.

Besides *Gazza minuta* I collected 15 other species of the Leionathidae. Investigation of these species reveals that they all possess a luminous organ of a type similar to that of *Gazza minuta*.

Since the luminescence of these fishes of the family Leionathidae was, I thought, unknown, I published the results of my investigations in 1940. I now present the results in revised form.

*Gazza minuta* occurs in clear water in Palao at a depth of about 30 meters and *Leionathus equulus* lives in turbid water in the vicinity of mangrove trees at a depth of 1-2 meters. In Palao and Yap, *L. equulus* ranged in length from 60 to 70 mm.; in Ponape it was 180 mm. long; and in Sandakan, 200 mm. long. In Sandakan, the Chinese fishermen catch these fishes in nets and bring them every morning for sale in the Sandakan fish market.

In Japan there are three species, *L. argenteum* (Japanese name Uchi-Hiiragi), *L. rivulatum* (Oki-Hiiragi), and *L. elongatus* (Hime-Hiiragi).

*L. argenteum* and *L. rivulatum* are common on the southern coast of Japan. They are extremely abundant in Nagasaki where they are called Gira-gira or Gira. In Kōchi they are called Nirogi. In the bay of Urado near the city of Kōchi many old men may be seen fishing for Nirogi on any fine autumn day. *L. argenteum* is caught almost entirely by hook and line. This species lives in rather turbid water along the shores of the river estuaries, and it is from this fact that the

TABLE 1  
DATA ON COLLECTIONS OF LUMINOUS LEIOGNATHIDAE

SPECIES	PLACE OF COLLECTION	DATE OF COLLECTION
<i>Gazza minuta</i> (Bloch)	Palao	June 1937, Feb. 1938
Koban-Hiiragi (Japanese)	Yap	August 1937
Kekek, Kekek labu (Malay)	Sandakan, B. N. Borneo	March 1938
	Ponape	March 1940
	Singapore	March 1943, Nov. 1944
	Penang, Malay	June 1943
	Batavia	March 1945
<i>Secutor insidiator</i> (Bloch)	Sandakan, B. N. Borneo	March 1938
<i>Secutor ruconius</i> (Ham.-Buch.)	Sandakan	March 1938
Ukekuchi-Hiiragi (Japanese)	Singapore, Penang	June 1943
	Batavia	March 1945
<i>Leiognathus equulus</i> (Forsk)	Palao, Yap	June, Aug. 1937; Feb. 1938
Seitaka-Hiiragi (Japanese)	Truk	March 1940
Kekek gadabang (Malay)	Ponape	March 1940
	Sandakan	March 1938
	Itoman, Okinawa	March 1938
	Singapore, Penang	June 1943, Aug. 1944
	Batavia	March 1945
<i>L. fasciatus</i> (Lacép.)	Palao	June 1937, Feb. 1938
	Ponape	March 1940
	Truk	March 1940
	Sandakan	March 1938
	Singapore	Sept. 1943
<i>L. lineolatus</i> (Cuvier & Valenciennes)	Palao	Oct. 1937
Ito-Hiiragi (Japanese)	Palao	March 1940
	Palao	Oct. 1943
<i>L. splendens</i> (Cuvier)	Sandakan	March 1938
	Singapore	Sept. 1943
<i>L. daura</i> (Cuvier & Valenciennes)	Sandakan	March 1938
	Singapore	Oct. 1944
<i>L. bindus</i> (Cuvier & Valenciennes)	Davao, Philippines	Aug. 1939
<i>L. berbis</i> (Valenciennes)	Singapore	Nov. 1943
<i>L. dussumieri</i> (Cuvier & Valenciennes)	Singapore	Oct. 1944
<i>L. stercorarius</i> Evermann & Seale	Singapore	Nov. 1944
<i>L. elongatus</i> Günther	Izu, Japan	Oct. 1938
Hime-Hiiragi (Japanese)		
<i>L. rivulatum</i> (Temminck & Schlegel)	Tosa, Japan	Oct. 1939
Uchi-Hiiragi (Japanese)		
<i>L. argenteum</i> (Lacépède)	Tosa, Japan	Oct. 1939
Oki-Hiiragi (Japanese)		

species derives its name of Uchi Nirogi—inshore nirogi. It is always present in the street markets. *L. rivulatum* occurs in the off-shore waters, and is taken only in nets. It is plentiful in the Mimase fish market near the city of Kōchi. Both species are usually dried for

sale, and are very good to eat.

*L. elongatus* is not common. It is also an off-shore species. I obtained my specimens off Suzukawa-Shizuoka Prefecture.

From the Itoman market, Ryukyu Islands, I obtained two specimens of *L. equulus* and



*Gazza minuta*. Both specimens were the same as those found in tropical seas.

In 1943–1944 I collected in Singapore the species as listed in the accompanying table.

Around Singapore and the Malay Peninsula these kinds of fishes are easily obtained in all seasons from the fishing trap known as the Kelong. Fowler (1938) reported 12 species of this family in Malaya.

### The Luminous Organ

*Gazza minuta*: Externally this fish does not present any unusual features, and it was only by a careful observation of the living fish by night that the bluish-white luminescence of the lower half of the body was revealed.

The source of the luminescence is a swollen ring of gland-like substance which encircles the oesophagus. It is covered with a white membrane except at two points, one located dorsally and the other ventrally. These appear as two small bean-shaped areas of a yellowish-white color. The ring contains a gland which has two openings (Fig. 4, op) which lead into the oesophagus.

The swim bladder and the thoracic and ventral muscles are so modified as to increase the efficiency of the light-producing mechanism. The swim bladder is lined with a remarkably bright silvery reflecting surface and the muscles of the thorax and the ventral parts of the body are translucent but somewhat cloudy. The swim bladder has no reflecting surface at its posterior end, which is translucent. Part of the dorsal silver lining is continued under the spinal column and acts as a reflector for the light which is transmitted backward through the translucent end of the bladder. Light is emitted from the two bean-shaped areas only, the dorsal one illuminating the swim bladder, the ventral one the thoracic and ventral muscles.

If the diagram of the longitudinal section of the fish through the swim bladder is studied, it will be seen that the anterior end of

the swim bladder forms a parabola, and that a bean-shaped light spot (one part of the luminous ring gland) is at its focus. We

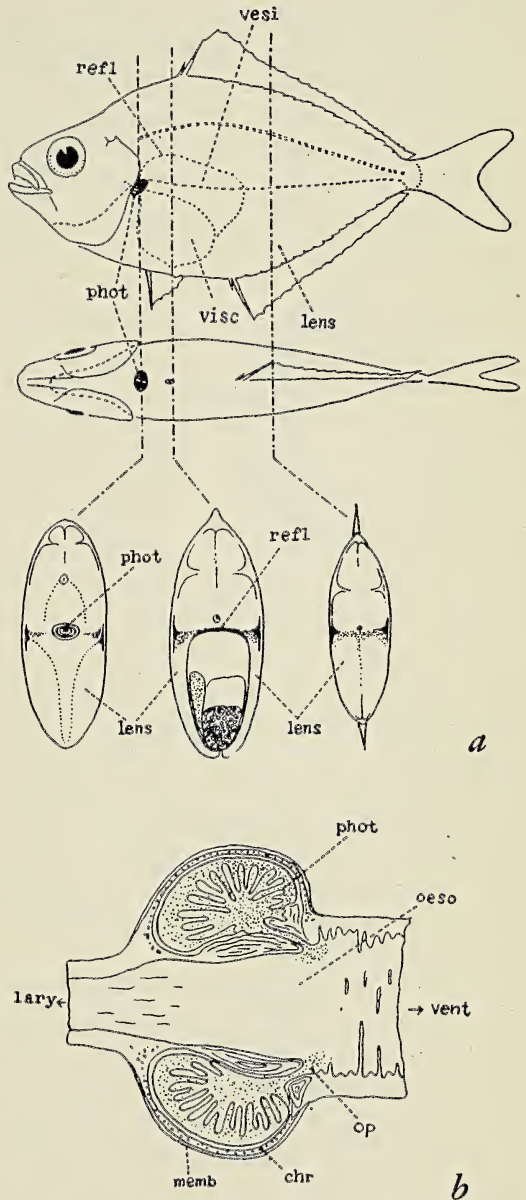


FIG. 4. *a*, Diagrammatic figure of the luminous organ of *Gazza minuta* (Bloch). *b*, Longitudinal section of the luminous gland of *Gazza minuta* (Bloch): phot, luminous gland; refl, reflector; lens, lens; visc, internal organ; vesi, swim bladder; chr, chromatophore; memb, membrane; op, opening of luminous gland; oeso, oesophagus; larye, larynx; vent, stomach.

have, in fact, a remarkably efficient parabolic reflector which reflects the emitted light backward even as far as the muscles of the caudal peduncle.

The ventral light spot directs its light downward, and, because of the cloudy translucent muscles of the thorax and abdomen, a diffused luminescence is seen in this area. Because of the presence of a white opaque membrane extending dorsally from the upper borders of the abdominal muscles of both sides, no light reaches the dorsal part of the body.

The bean-shaped areas are furnished with chromatophores, and it is perhaps due to their expansion that the light can be shut off, and by their contraction displayed. Possibly the white membrane which covers the ring can be contracted to cover the light spots, but this I was unable to confirm. Normally it is expanded to uncover them.

The complete luminous organ therefore consists of three components, possibly four: (1) the luminous ring gland; (2) the reflector; and (3) the lenses; with possibly (4), a shutter for the light spots which may be opened or closed either by the chromatophores or by the white covering membrane of the ring working independently or simultaneously with the chromatophores. In recently dead specimens these spots are closed by the membrane, but the gland material is still luminous.

As previously stated this fish differs from other luminous fish by its unusually large luminous area, utilizing in fact half the muscles of its extremely complicated body structure. The luminous glands are situated in the body, and may be considered to be of an indirect or reflecting type, functioning by reflected light in the same way as described for *Acropoma japonicum*; but *Gazza minuta* is not only provided with a membrane and chromatophores for displaying its luminescence, it has a far more complex luminous organ than *Acropoma japonicum*.

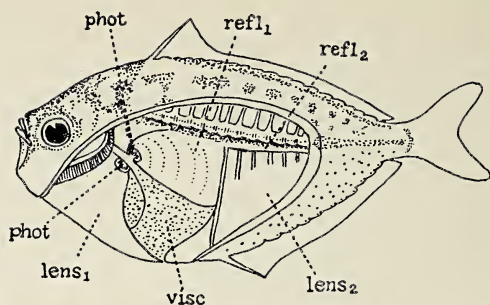


FIG. 5. Diagrammatic figure of the luminous organ of *Secutor insidiator*: phot, luminous gland; refl<sub>1</sub>, refl<sub>2</sub>, reflectors; lens<sub>1</sub>, lens<sub>2</sub>, lenses; visc, internal organs.

*Secutor* spp.: *Secutor insidiator* (Fig. 5) and *S. ruconius* are luminous Leiognathidae, similar to *Gazza minuta*, but possessing a relatively larger luminous gland than does *G. minuta*. It is yellow in fresh material instead of white as in *G. minuta*.

The reflector is very efficiently arranged and is lined with a bright glossy surface.

The ventral muscles are cloudy and translucent. The ventral cavity walls are extremely thin and, because of this, its luminosity is greater than that of any of the other members of the family Leiognathidae.

*Leiognathus* spp.: There are many species of *Leiognathus*, varying in length from 50 mm. to 200 mm. With the exception of the male *L. rivulatum* they have comparatively small luminous glands. Even when compared with *Gazza* and *Secutor*, this has a comparatively small luminous body and thick ventral cavity walls, which are only moderately translucent, thus diminishing the brightness of the luminosity.

The species *L. equulus*, *L. fasciatus*, *L. splendens*, *L. lineolatus*, *L. bindus*, *L. berbis*, *L. argenteum*, *L. dussumieri*, *L. stercorarius*, and *L. daura* are also only moderately luminous. There is an interesting feature of the Japanese species, *L. rivulatum*, viz.: the luminous gland of the male is either very large or else very small. I am of the opinion, though by no means certain, that this differ-



ence in size is due to age. The luminous gland of the female is smaller and the luminosity of the female is therefore very weak compared with that of the male.

The luminous gland of *L. rivulatum* differs from that of all other Leiognathidae in

that it does not surround the oesophagus completely, but occurs as an external swelling on the dorsal part only.

*L. elongatus* also possesses a very small luminous gland with a poor reflector; in consequence its luminosity is feeble.

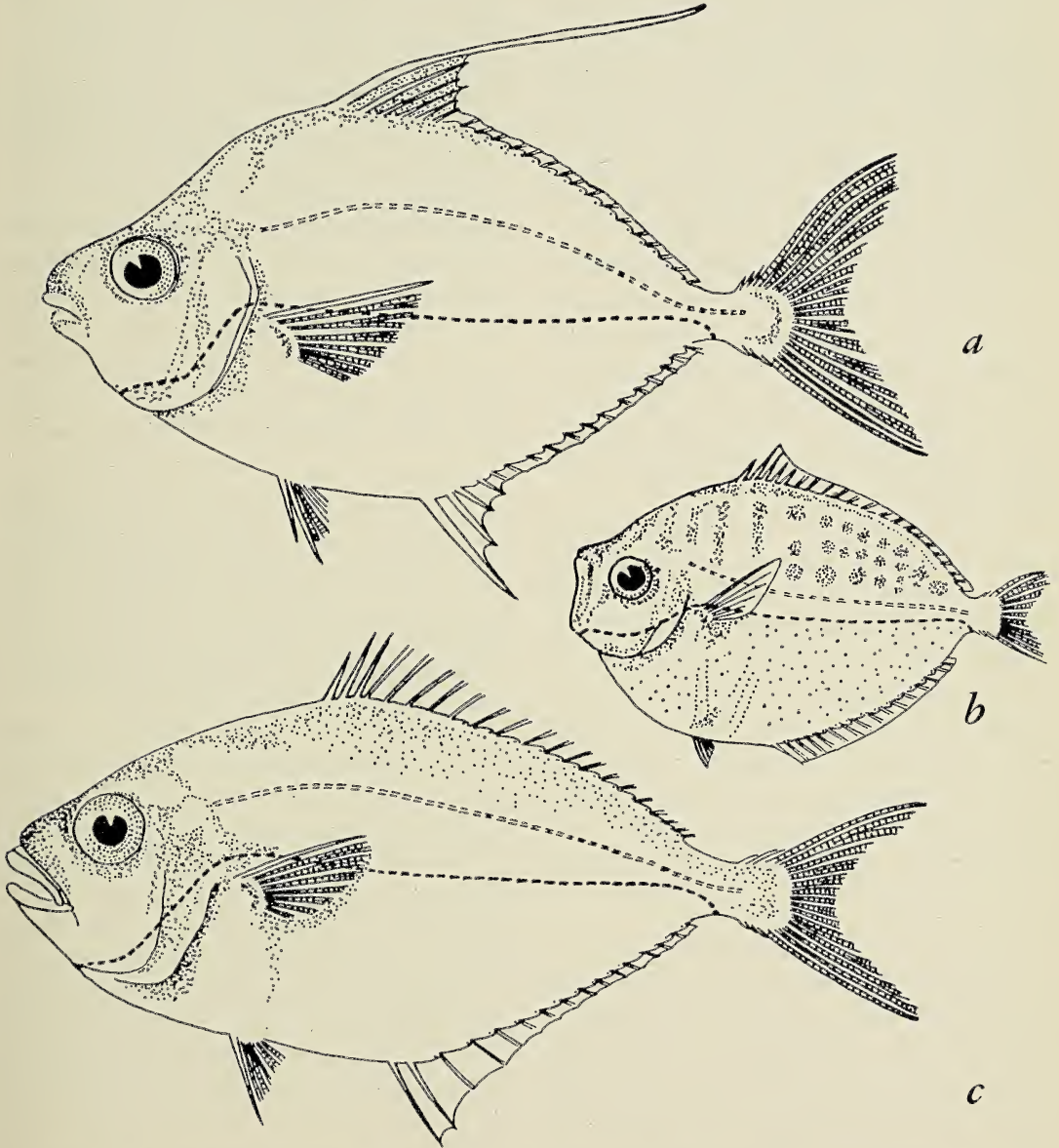


FIG. 6. *a*, *Leiognathus equulus* (Forsk.); *b*, *Secutor insidiator* (Bloch); *c*, *Gazza minuta* (Bloch). The luminous organs are not seen externally, so that the fish look like common non-luminous fishes, but the lower half of these fish bodies, namely, the parts below the black lines, are a lightning-like bluish-white color.

### *Remarks on the Luminescence*

A specimen of *Gazza minuta* and one of *Secutor insidiator* were put into a tank of sea water in a dark room and their luminescence was studied. No luminescence could be seen when the fish were viewed dorsally, but if they were viewed laterally a diffuse bluish-white luminosity could be seen. If the area where the transparent scales are arranged was examined directly or obliquely from below, a faint bluish light was seen, emanating from the chest, thorax, abdomen, and tail areas. The light showed uninterruptedly in these areas. It did not shine brilliantly, but was feeble and diffused.

If the fish received a strong stimulus or was removed from the water, the lower part of the body lighted up brilliantly, most strongly in the thoracic and abdominal regions. This sudden increase in brilliancy was accompanied by a croaking sound, the production of which is a peculiarity of the *Leiognathidae*.

If during this brief period of maximum brilliancy the fish was enveloped in a cellophane wrapper and was laid on a photographic film, it would produce a bright image.

After death the luminous gland was surrounded by the membrane and the light was no longer visible, but if the fish was dissected and the membrane covering the gland was removed, this membrane was found to be luminous and, when kept in an ice box at 5–10° C., it remained so for 2 days.

### *Contents of the Luminous Gland*

When the substance of the luminous gland is freshly made up as a 3 per cent salt emulsion, the whole of the emulsion will be luminescent, but if it is allowed to stand, only the upper layer exposed to the atmosphere will glow while the deeper lower layer becomes non-luminous. When shaken up in air the whole emulsion becomes luminous again.

Luminescence is greatest at a temperature of 26°–30° C. in the tropics (in Japan at about 20° C.) and becomes feeble at 4° C. When the temperature is raised, it increases and finally disappears at 45° C., but after once attaining this latter temperature it fails to recover its luminosity even when cooled again. An emulsion in nearly 3 per cent NaCl gives the best results; an emulsion in distilled water produces no light. If such a distilled-water emulsion is centrifuged the upper clear solution is non-luminous but the sediment is luminous. Microscopically this emulsion is made up of disintegrated particles of gland cells with innumerable bacteria, and it appears from the results of these experiments that the contents of the luminous gland consist of luminous bacteria. In order to test this, isolation experiments were carried out to cultivate them in a 3 per cent NaCl agar-agar culture medium.

### *Culture of the Luminous Bacteria*

A pure culture of the luminous bacteria from the luminous glands was prepared by the usual bacteriological techniques. After 8–10 hours a small, round, transparent and luminous colony appeared. From this start a pure culture which was free from any contaminating bacteria was obtained.

It was clearly demonstrated that the same kind of fishes always had the same kind of luminous bacteria and that the *Leiognathidae* of the tropical sea and those of Japan possessed luminous bacteria of the same group, with only slight variations probably due to the effects of temperature. There is a curious feature, viz., the bacteria in culture are not as brilliant as are those in the gland, probably because of the unsuitability of the medium for greatest luminosity. The details of the bacteriological work will be presented elsewhere.

### SUMMARY

Some luminous fishes show no outward peculiarities in structure or appearance and



resemble ordinary non-luminous fish. This is because the luminous body lies inside the fish and cannot be seen from outside.

These fishes differ from other luminous fishes by their unusually large luminous areas, which utilize as much as one half or one third of the muscles of the extremely complicated body structure of the fish.

The luminous fishes hitherto known are provided with a direct radiating luminous organ, while the fishes described in this paper possess an indirect radiating luminous organ. These organs of indirect emission are peculiar organs of a novel type, which appear to be confined to *Acropoma* species, the Leiognathidae, and *Apogon marginatus* Döderlein.

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# Sea Temperatures, Hawaiian Island Area<sup>1</sup>

A Study of the Distribution of Ocean Temperatures in the Surface and Subsurface Layers  
Based upon Bathythermograph Observations

DALE F. LEIPPER AND ERNEST R. ANDERSON<sup>2</sup>

## INTRODUCTION

SINCE 1940 the supply of available sea-temperature information has been greatly increased through the use of the bathythermograph (Spilhaus, 1940), an instrument which may be lowered from moving vessels to provide a continuous trace of temperature against depth. The temperature values are usually accurate to within  $\pm 0.3^\circ$  F. Greatest depths attained are approximately 180, 450, or 900 feet, depending upon the type of bathythermograph used. A detailed sea-temperature study of the Hawaiian Island area (the area from  $15^\circ$  to  $30^\circ$  north latitude and  $150^\circ$  to  $165^\circ$  west longitude) was prepared by the Bathythermograph Section at Scripps Institution of Oceanography (Leipper and Anderson, 1948; Hiatt, 1948). This study, made from 5,407 observations, is the basis of the summary presented here. A similar study was made in the Philippine Island area (Leipper and Wood, 1947) but has not yet been published.

### *Purpose of the investigation*

The purpose of this investigation is three-fold: (1) to show the horizontal and vertical distribution of temperature; (2) to show the

amount of data that is available and how it is distributed; and (3) to further the development of a model temperature-distribution study that may in the future be used for other regions.

### *Availability of bathythermograph data*

The file of bathythermograms for the Pacific and Indian Oceans is maintained at Scripps Institution of Oceanography, La Jolla, California, and at the U. S. Hydrographic Office, Washington, D. C. Copies of observations may be requested from the Hydrographic Office.

*Acknowledgments:* Clerical and statistical assistance was furnished by Misses A. Kutz, V. Wilburn, M. Hunter, M. Oakes, E. Trowbridge, and Mrs. B. Rimbach. Drafting was done by Mrs. M. Robinson and photographic work by Mr. P. Williams.

## DISTRIBUTION OF BATHYTHERMOGRAMS

The bathythermograph observations used for this investigation cover the period from January, 1941, to November, 1947. Of the bathythermograms available, 5,377 were suitable for use.

The time distribution of the bathythermograms is shown by Tables 1, 2, and 3 following the text. Table 1 shows the yearly percentage distribution; Table 2, the total monthly percentage distribution; and Table 3, the monthly percentage distribution in different years. The space distribution of the bathythermograms is shown in Figure 1. (Figures appear at the end of the text and tabular material begins on page 232.)

<sup>1</sup>Contributions from the Scripps Institution of Oceanography, University of California, New Series No. 468. This work represents results of research carried out by the University of California, under contract with the Office of Naval Research and the Hydrographic Office of the Department of the Navy.

<sup>2</sup>Now associated with the Department of Oceanography, Agricultural and Mechanical College of Texas, College Station, Texas, and the Oceanographic Branch, Navy Electronics Laboratory, San Diego, California, respectively.



Two groups of cruises, designated as the *H* and *Q* cruises, were made near the entrance to Pearl Harbor during 1944 and the early part of 1945. The following tabulation shows the dates of these cruises as well as the number of bathythermograph observations taken.

*H* AND *Q* CRUISE DATA

CRUISE	DATE	NUMBER OF BATHY- THERMOGRAMS
Q-1	2/24/44– 3/29/44	60
Q-2	3/29/44– 4/22/44	60
Q-3	4/23/44– 5/14/44	60
Q-4	5/15/44– 6/26/44	60
Q-5	6/27/44– 9/ 4/44	60
Q-6	9/15/44–11/13/44	60
Q-7	11/14/44– 2/12/45	60
Q-8	2/12/45– 2/20/45	7
H-1	3/13/44– 3/29/44	42
H-2	3/29/44– 4/17/44	56
H-3	4/17/44– 5/ 6/44	57
H-4	5/ 6/44– 5/30/44	60
H-5	6/ 1/44–10/ 9/44	108
H-6	11/16/44– 2/20/45	63

#### HORIZONTAL TEMPERATURE DISTRIBUTION

*Horizontal temperature distribution based on averages by 1-degree quadrangles of latitude and longitude*

The horizontal distribution of average temperature at the surface and at depths of 100 feet, 200 feet, and 300 feet is shown in Figures 2 to 13 for each of the 12 months of the year. March and September average temperatures were, respectively, lowest and highest of the year. June and December were months having temperature distributions typical of months of transition.

In preparing the monthly average temperature charts, the following procedure was used: At each depth level, all available temperatures for each 1-degree quadrangle were averaged by months. To obtain time continuity, the monthly averages for each quadrangle where there were sufficient data were plotted against time, and a curve, smoothed visually, was drawn through the points. Monthly average temperatures were then read

from this smoothed curve. The values for each month were plotted on a map by position, and the isotherms were drawn.

The ocean current systems which are present affect the horizontal temperature distribution. In March the southern portion of the Hawaiian Island area is under the influence of the northeast trade winds with a resulting ocean current toward the west known as the North Equatorial Current. In the northerly portion of the area the North Pacific Current flows toward the southeast. Between these two currents as shown in Figure 14 is a region where the flow is variable (Sverdrup, Johnson, and Fleming, 1946: 723, appendix, Chart VII). This region coincides with the region where the pattern of isotherms is most irregular, as shown in Figures 2 to 13.

#### *The extremes of average temperature*

For each month of the year, at particular depths, the maximum average monthly temperature occurring in any 1-degree quadrangle of the Hawaiian Island area was selected. Similarly, the minimum average was obtained. These, together with the differences between them, are presented in Table 4 at several depths for each month. At the surface and at 100 feet, the differences are smaller during the summer than during the winter. At 200 and 300 feet, the differences appear to be almost constant.

Table 5 (page 233) shows results of analysis of the smoothed annual temperature-variation curves which were drawn for each 1-degree quadrangle as explained earlier. An examination of the table shows that the minimum occurred the greatest percentage of the time in March at all levels except 300 feet; and the maximum, in September at all levels except 300 feet. At 300 feet the minimum occurred most often in April and the maximum most often in October.

Figures 16 and 17 present the maximum and minimum monthly average temperatures, respectively, for the surface and the 100-

200-, and 300-foot levels. To obtain Figure 16, the highest monthly average temperature at each depth in each quadrangle was plotted, regardless of the month or year in which it occurred, and isotherms were drawn. Figure 17 was prepared similarly for lowest monthly average temperatures.

The highest single surface temperature recorded in the Hawaiian Island area was 90° F. at 19° N and 157° W in August, 1942, while the lowest single temperature recorded was 60.9° F. at 28° N and 163° W in January, 1947.

#### *Annual sea temperatures at a depth of 400 feet*

As is apparent in Figures 22 and 27, sea temperatures at a depth of 400 feet have only a small annual variation. Values for all months of the year have therefore been averaged together by 1-degree quadrangles to obtain the annual average. These annual averages were plotted by position and isotherms drawn (see Figure 15). This figure, when compared with Figures 22 and 27, indicates that at 400 feet the variation of sea temperature with position greatly exceeds the variation with time.

#### *Comparison of average temperatures in different years*

Figure 18 compares the annual variation of temperature at the surface, 100 feet, 200 feet, and 300 feet for each of the years 1943 to 1947 with the average annual variation for all years combined. There is considerable difference between the curves representing different years. The year 1943 was warmer than average at the surface and 100 feet. Not enough data were available to show the deviation at 200 feet and at 300 feet in this year. The year 1944 was virtually an average year at the upper two levels, while at the two lower levels there was some variation from the average. The year 1945 was definitely a warmer-than-average year in the upper two levels, while in the lower two it was generally

warmer with a few months colder than average. The first part of the year 1946 was definitely warmer than average, while the latter part of the year was colder than average at all levels. The year 1947 was a colder-than-average year at all levels with the deviation being the greatest in the upper 100 feet.

#### *Average temperature in the vicinity of Oahu*

Figure 19 shows the temperature distribution in the vicinity of Oahu for the surface, 100 feet, 200 feet, and 300 feet. The isotherms at each depth are based upon averages computed for each 10-minute quadrangle of latitude and longitude. Thus the details of the average temperature distribution near Oahu are shown. In this region many observations are available and detailed information may have practical value.

### VERTICAL TEMPERATURE DISTRIBUTION

#### *Southwest-northeast cross section*

Figures 20 and 21 present average southwest-northeast temperature-depth sections for winter and summer months, respectively. All available bathythermograms for the two periods of time, and within the band denoted in Figure 1, were used to obtain the averages at various positions and depths. These averages form the basis of the sections.

#### *Monthly average temperature-depth curves*

Figure 22 shows curves through the average temperatures at different depths for a 5-degree quadrangle covering the area 20° to 25° N and 155° to 160° W. These curves were obtained by averaging all available temperatures for each month at 10-foot depth intervals down to 100 feet and at 25-foot intervals down to 425 feet, plotting these averages against depth, and joining the points. Such curves do not show the typical temperature-depth structure because of smoothing which occurs in averaging. The number of temperatures included in the average is shown beside each point.



Figure 23 shows the average temperature-depth curves for two specific points. The curves labeled "H" are taken from *H* cruise data. These cruises consisted of 386 bathythermograph observations from March, 1944, to February, 1945. All data were collected at  $21^{\circ} 18' \text{ N}$  and  $157^{\circ} 53' \text{ W}$ , approximately 0.75 mile south southwest of Honolulu in 100 feet of water. These data were averaged together by months with the results as shown in the figure. The curves labeled "Q" are taken from *Q* cruise data. These cruises consisted of 427 bathythermograms from February, 1944, to February, 1945. The station was located at  $21^{\circ} 18' \text{ N}$  and  $157^{\circ} 58' \text{ W}$  about 1.75 miles due south of the entrance to Pearl Harbor in about 600 feet of water.

These two stations are located approximately 5 miles apart, and the data were taken during the same year. It is interesting to note that during the months of March and April the average curves were identical, but during the other months the *H* cruise data showed appreciably lower temperature at all depths.

#### *Typical bathythermograms*

Figure 24 contains copies of actual bathythermograms selected as typical of a northern and a southern portion of the area under study for the months of March, June, September, and December. These single records show several prominent features which are not apparent in curves drawn through average temperatures at selected depths. One of these features is the deep layer of nearly isothermal water which is present on several of the individual curves. Another is the strong thermocline. Each of these characteristics is typical of nearly all individual bathythermograms in this area but the process of averaging and the decreasing frequency of temperature readings with depth causes them to disappear from the average temperature-depth curves. Thus it is desirable to consider typical single observations as well as average curves.

#### *Depth of the virtually isothermal layer*

The average depth of the virtually isothermal layer for summer and winter periods is shown in Figure 25. The charts were prepared by reading from the bathythermograms the layer depth to the nearest foot and averaging the results by 1-degree quadrangles. These data were then plotted, and isolines of depth were drawn. The virtually isothermal layer is, on the average, deeper than the 180-foot maximum depth for the "shallow" bathythermograph; hence, the "deep" bathythermographs are the only ones that reach the thermocline. As a result, only 40 per cent of the total number of bathythermograms available for this study were used in establishing the layer depth. Two conclusions may be drawn from Figure 25: the layer depth varies considerably with position; and during the winter the depth is greater than during the summer.

An attempt was made to draw layer-depth charts for each month of the year. Although many observations were available, the variability within any given month and any given quadrangle was so great that it was not possible to draw isolines that exhibited good continuity.

#### *Diurnal and annual variation of temperature*

In August, 1941, the U.S.S. "Pyro" took bathythermograph observations every hour in the area  $21^{\circ}$  to  $34^{\circ} \text{ N}$  and  $138^{\circ}$  to  $157^{\circ} \text{ W}$ . These data were analyzed by H. U. Sverdrup and others to determine the diurnal variation of temperature. Figure 26 shows the results of this analysis.

The wind-stirred layer at the time of these observations was approximately 120 feet thick with  $75^{\circ} \text{ F}$ . as the average temperature of the layer. Between the surface and 120 feet the temperatures were read at 30-foot intervals. The temperature differences between 120 feet and each other level were determined and plotted. The figure shows that the upper layer is nearly isothermal during the early

morning, but that the vertical gradient increases as the effect of solar radiation is felt. The time of maximum temperature occurs later at greater depths because time is required for heat to reach these depths by conduction.

The annual variation of temperature at subsurface depths in the area 20° to 25° N and 157° to 160° W is shown in Figure 27. The maximum temperature occurs at 400 feet approximately 1.3 months later than at the surface. A secondary maximum is indicated in January. The maximum shown at 400-foot level in April is probably not a real feature but one due to the uneven frequency distribution of observations.

ADDITIONAL DATA AVAILABLE

In addition to what has been published here, certain further investigations have been made and results are available from the Scripps Institution of Oceanography. Among these results are charts of the distribution of observations by months and hydrographic station data.

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SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1946. *The oceans, their physics, chemistry, and general biology.* x + 1087 pp., 265 figs., 7 charts. Prentice-Hall, Inc., New York.

TABLES

TABLE 1  
DISTRIBUTION OF BATHYTHERMOGRAMS  
BY YEARS

YEAR	PERCENTAGE
1941 . . . . .	3.2
1942 . . . . .	2.5
1943 . . . . .	16.0
1944 . . . . .	43.0
1945 . . . . .	15.1
1946 . . . . .	11.7
1947 . . . . .	8.6

TABLE 2  
DISTRIBUTION OF BATHYTHERMOGRAMS  
BY MONTHS

MONTH	PERCENTAGE
January . . . . .	7.1
February . . . . .	10.0
March . . . . .	10.4
April . . . . .	11.8
May . . . . .	9.9
June . . . . .	6.8
July . . . . .	7.2
August . . . . .	9.9
September . . . . .	9.2
October . . . . .	6.4
November . . . . .	6.3
December . . . . .	4.9



TABLE 3  
DISTRIBUTION OF BATHYTHERMOGRAMS BY MONTHS IN DIFFERENT YEARS  
(All figures are given as percentages.)

MONTH	1941	1942	1943	1944	1945	1946	1947
January . . . . .	0.0	0.0	0.3	5.8	23.4	2.1	7.0
February . . . . .	1.2	13.4	18.4	7.3	13.6	7.0	7.8
March . . . . .	5.3	0.0	13.0	8.7	9.4	1.7	30.0
April . . . . .	0.0	11.2	13.2	12.0	10.2	9.2	15.9
May . . . . .	2.4	22.4	9.5	14.1	2.8	2.9	11.3
June . . . . .	1.8	11.9	1.8	7.8	3.4	5.1	17.6
July . . . . .	3.5	0.0	5.0	7.2	6.9	9.1	10.4
August . . . . .	42.9	14.9	3.6	10.3	8.3	16.7	0.0
September . . . . .	2.9	9.7	12.1	8.0	6.3	20.5	0.0
October . . . . .	10.6	0.0	7.0	7.0	3.8	11.0	0.0
November . . . . .	24.7	0.0	5.0	6.6	5.4	8.7	0.0
December . . . . .	5.3	16.4	11.0	5.3	6.4	5.9	0.0

TABLE 4  
MAXIMUM AND MINIMUM MONTHLY AVERAGE TEMPERATURES  
AT DIFFERENT DEPTHS

	MAXIMUM				MINIMUM				DIFFERENCE			
	0	100	200	300	0	100	200	300	0	100	200	300
Depth in feet . . . . .												
January . . . . .	80	79	78	78	68	68	66	64	12	11	12	14
February . . . . .	79	78	78	77	67	66	65	64	12	12	13	13
March . . . . .	78	77	77	76	66	67	64	64	12	10	13	12
April . . . . .	78	77	77	76	68	68	64	64	10	9	13	12
May . . . . .	79	78	78	77	70	69	66	64	9	9	12	13
June . . . . .	80	80	79	77	74	71	68	64	6	9	11	13
July . . . . .	82	80	80	78	76	73	66	64	6	7	14	14
August . . . . .	82	81	81	79	77	75	68	66	5	6	13	13
September . . . . .	82	82	81	80	77	76	67	67	5	6	14	13
October . . . . .	82	82	82	80	76	75	68	66	6	7	14	14
November . . . . .	82	81	81	80	72	72	68	67	10	9	13	13
December . . . . .	80	80	80	79	70	70	67	66	10	10	13	13

TABLE 5  
MONTHS IN WHICH MAXIMUM AND MINIMUM TEMPERATURES OCCURRED MOST OFTEN ON  
SMOOTHED ANNUAL VARIATION CURVES WHICH WERE DRAWN  
FOR EACH 1-DEGREE QUADRANGLE

MINIMUM			MAXIMUM		
Depth	Month	Frequency	Depth	Month	Frequency
<i>Feet</i>		<i>Per cent</i>	<i>Feet</i>		<i>Per cent</i>
Surface	March	56.4	Surface	September	64.5
100	March	57.9	100	September	71.0
200	March	46.6	200	September	51.1
300	April	39.0	300	October	40.7
All	March	48.9	All	September	54.9

FIGURES

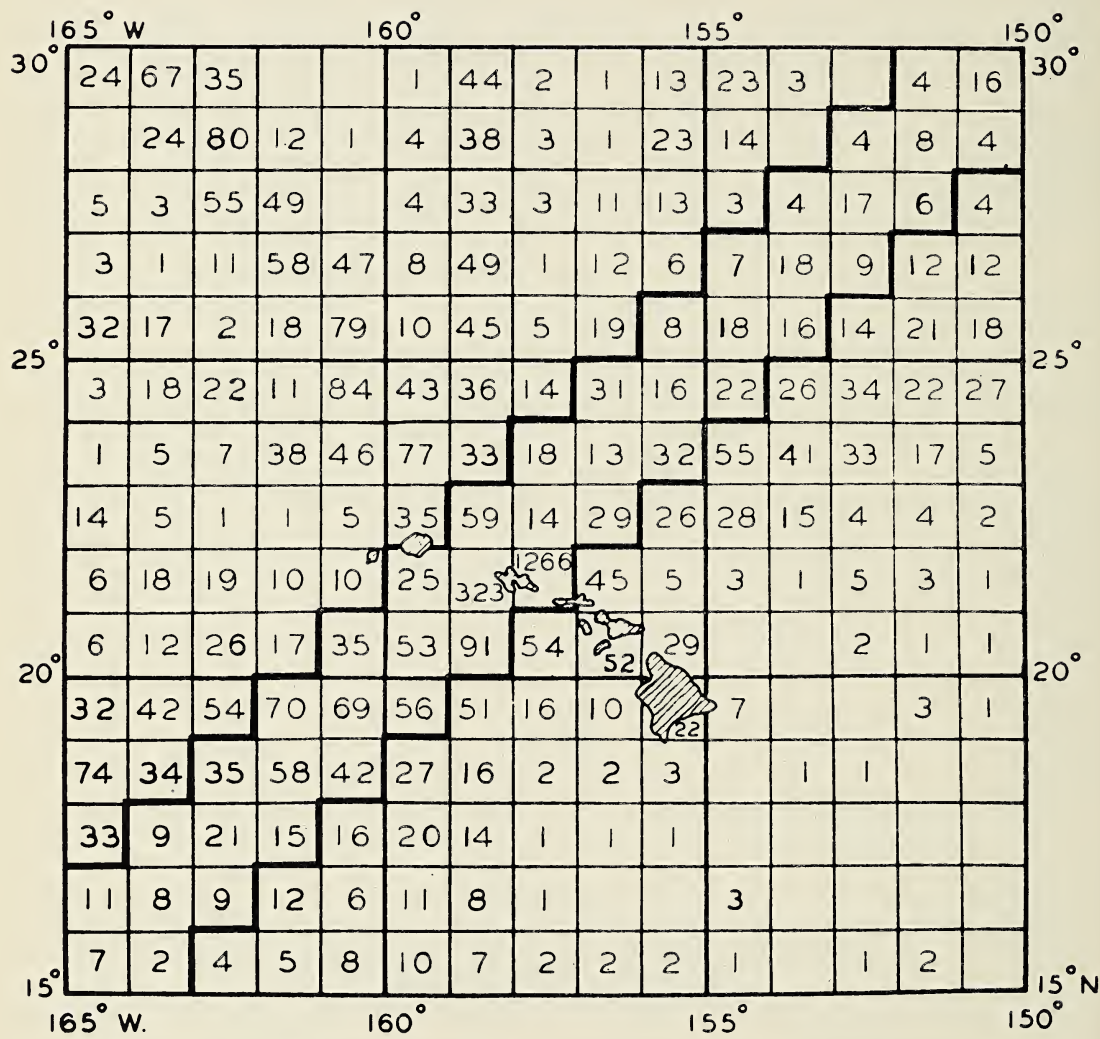


FIG. 1. Distribution of bathythermograph observations processed prior to November, 1947.



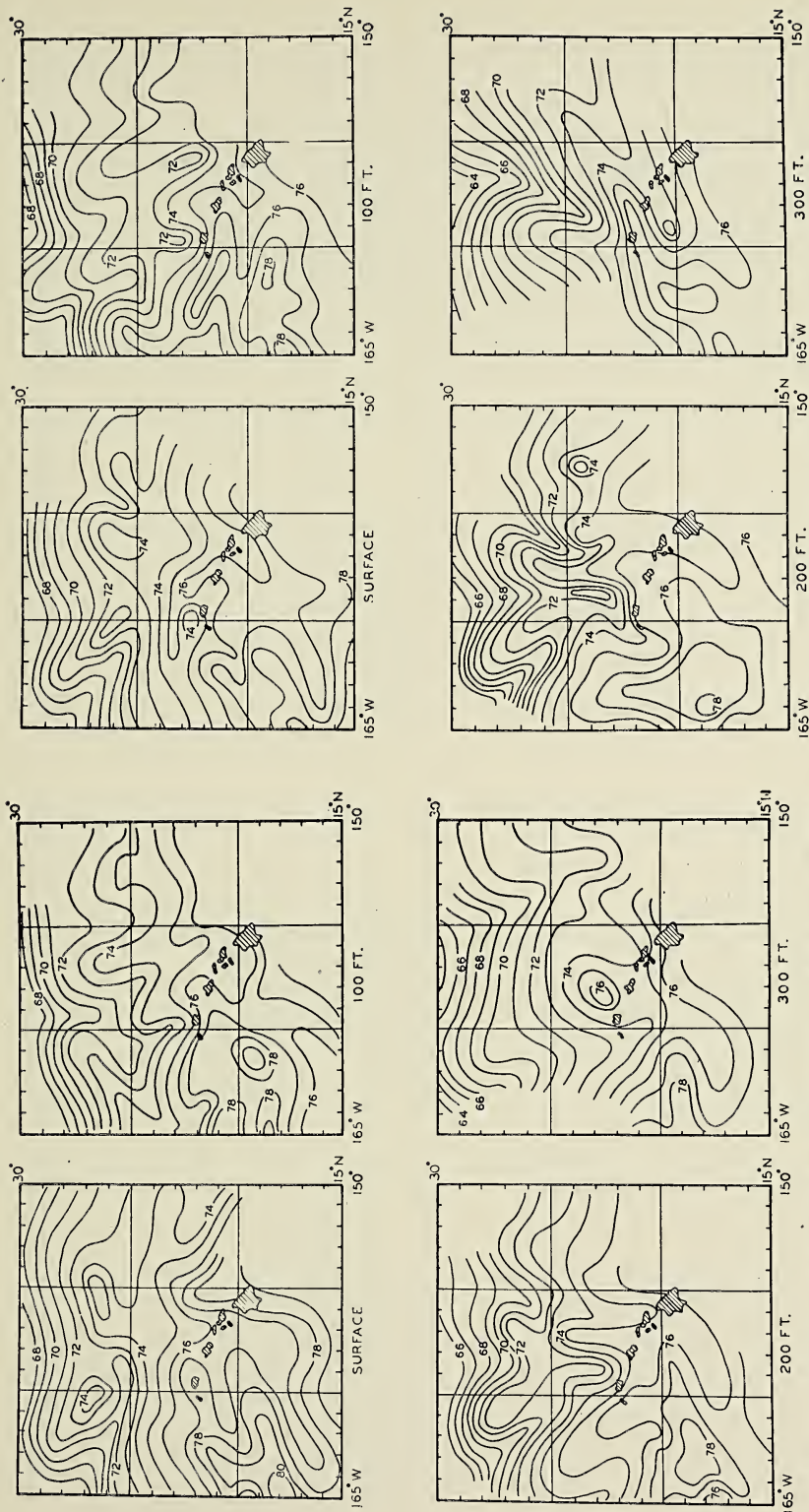


FIG. 2. JANUARY, average sea temperatures (° F.) at selected depths (1941-1947).

FIG. 3. FEBRUARY, average sea temperatures (° F.) at selected depths (1941-1947).

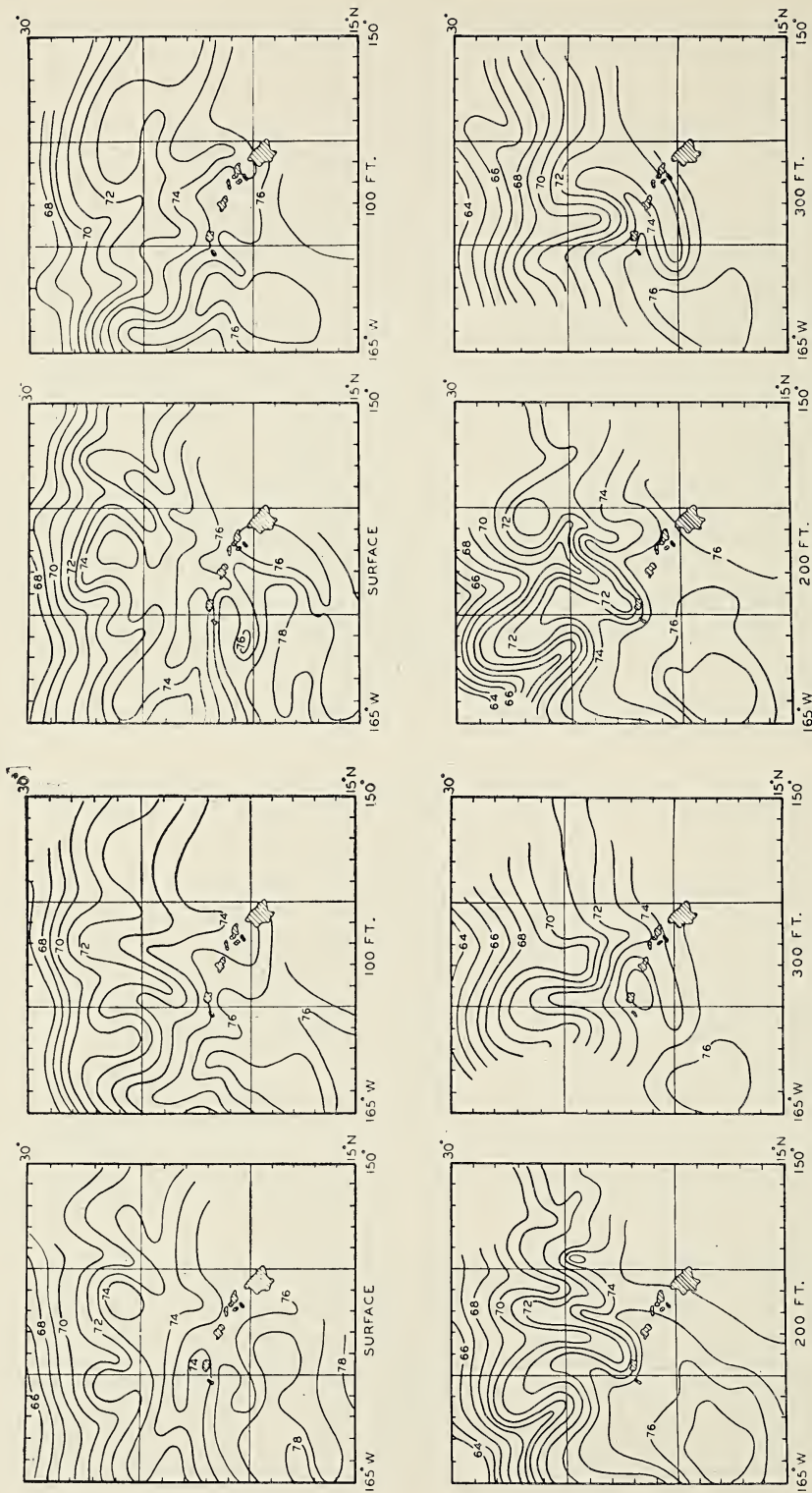


FIG. 4. MARCH, average sea temperatures ( $^{\circ}$  F.) at selected depths (1941-1947).

FIG. 5. APRIL, average sea temperatures ( $^{\circ}$  F.) at selected depths (1941-1947).



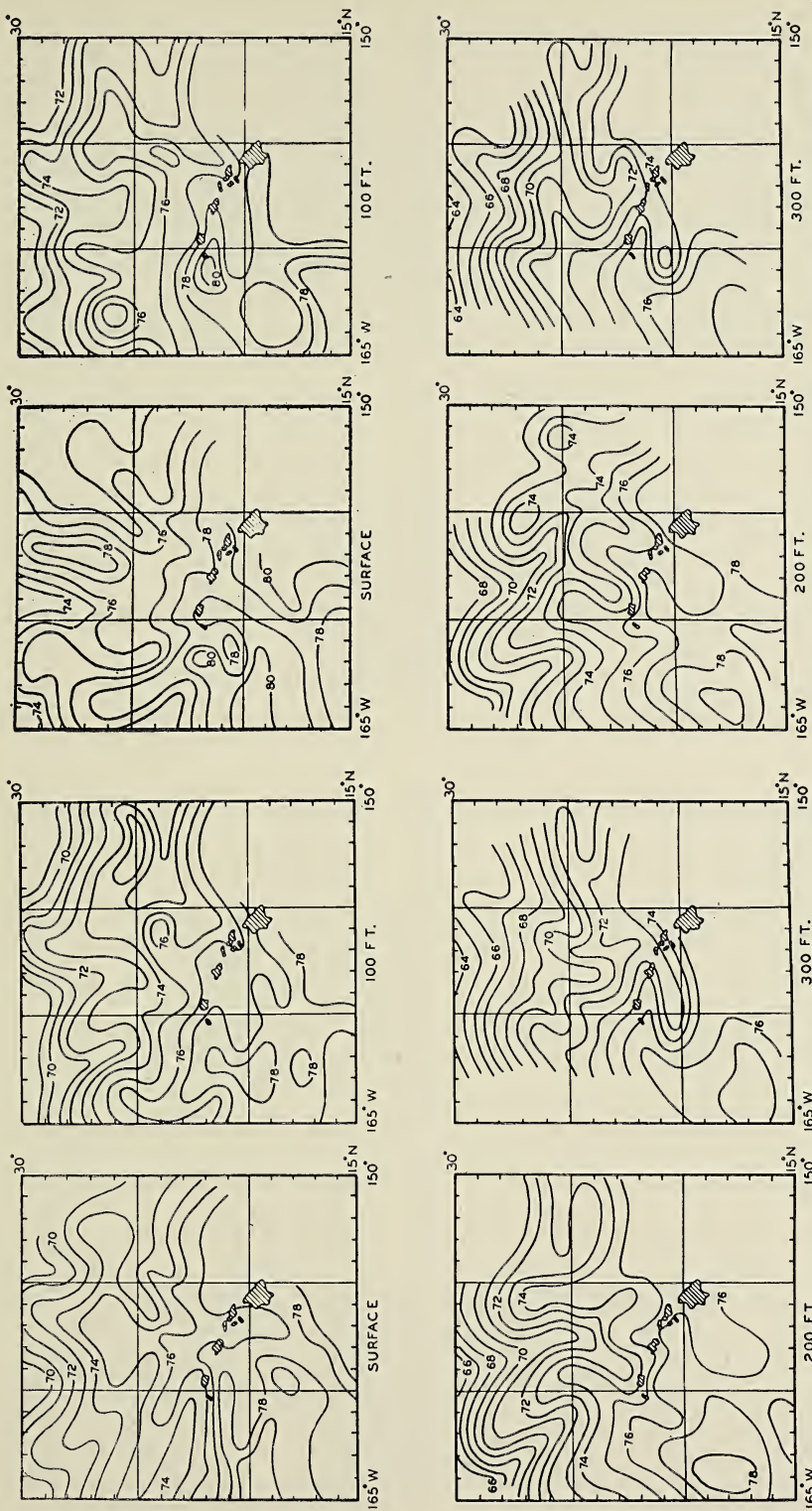


FIG. 6. MAY, average sea temperatures (° F.) at selected depths (1941-1947)

FIG. 7. JUNE, average sea temperatures (° F.) at selected depths (1941-1947).

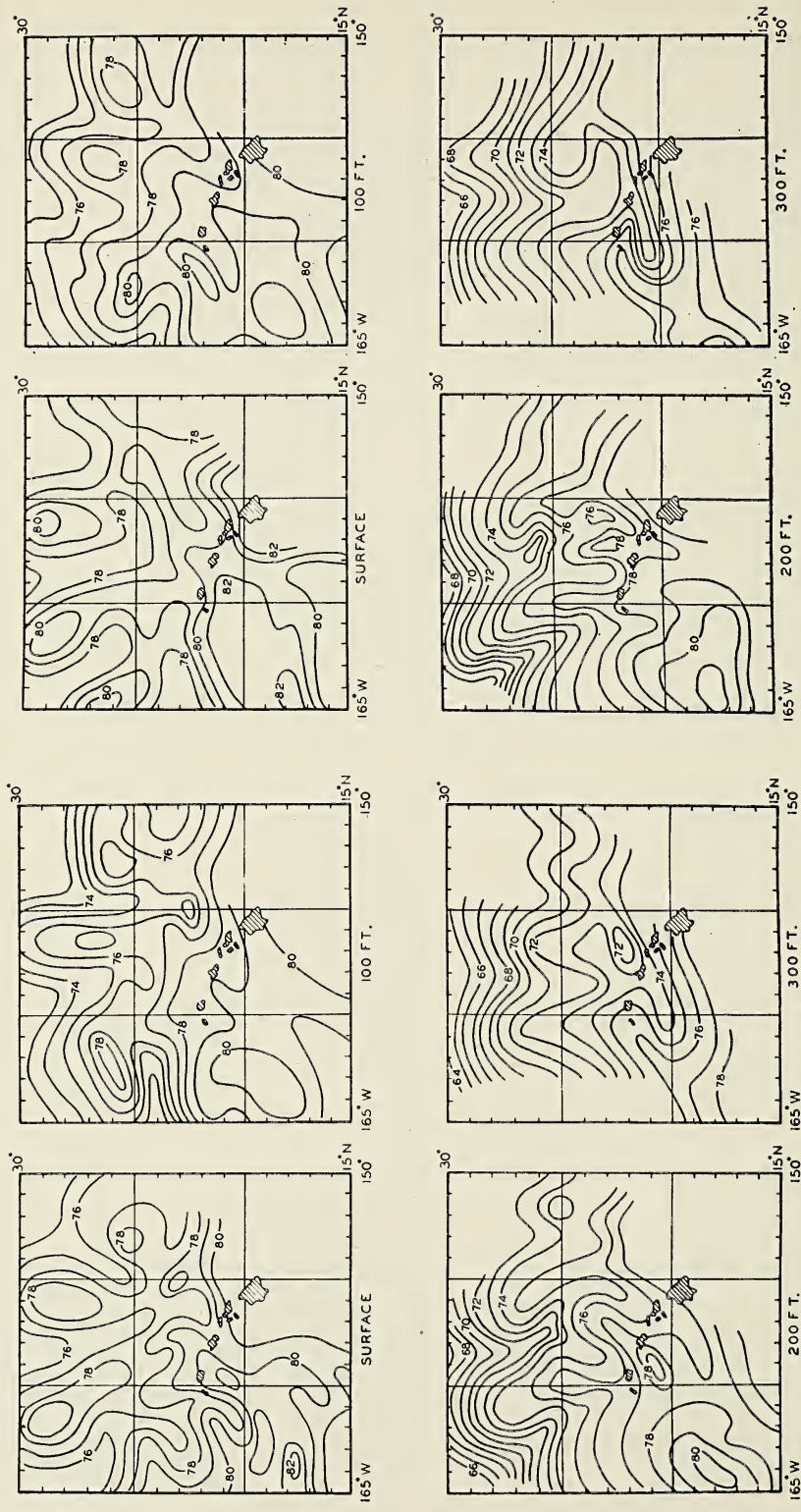


FIG. 8. JULY, average sea temperatures (° F.) at selected depths (1941-1947).

FIG. 9. AUGUST, average sea temperatures (° F.) at selected depths (1941-1947).



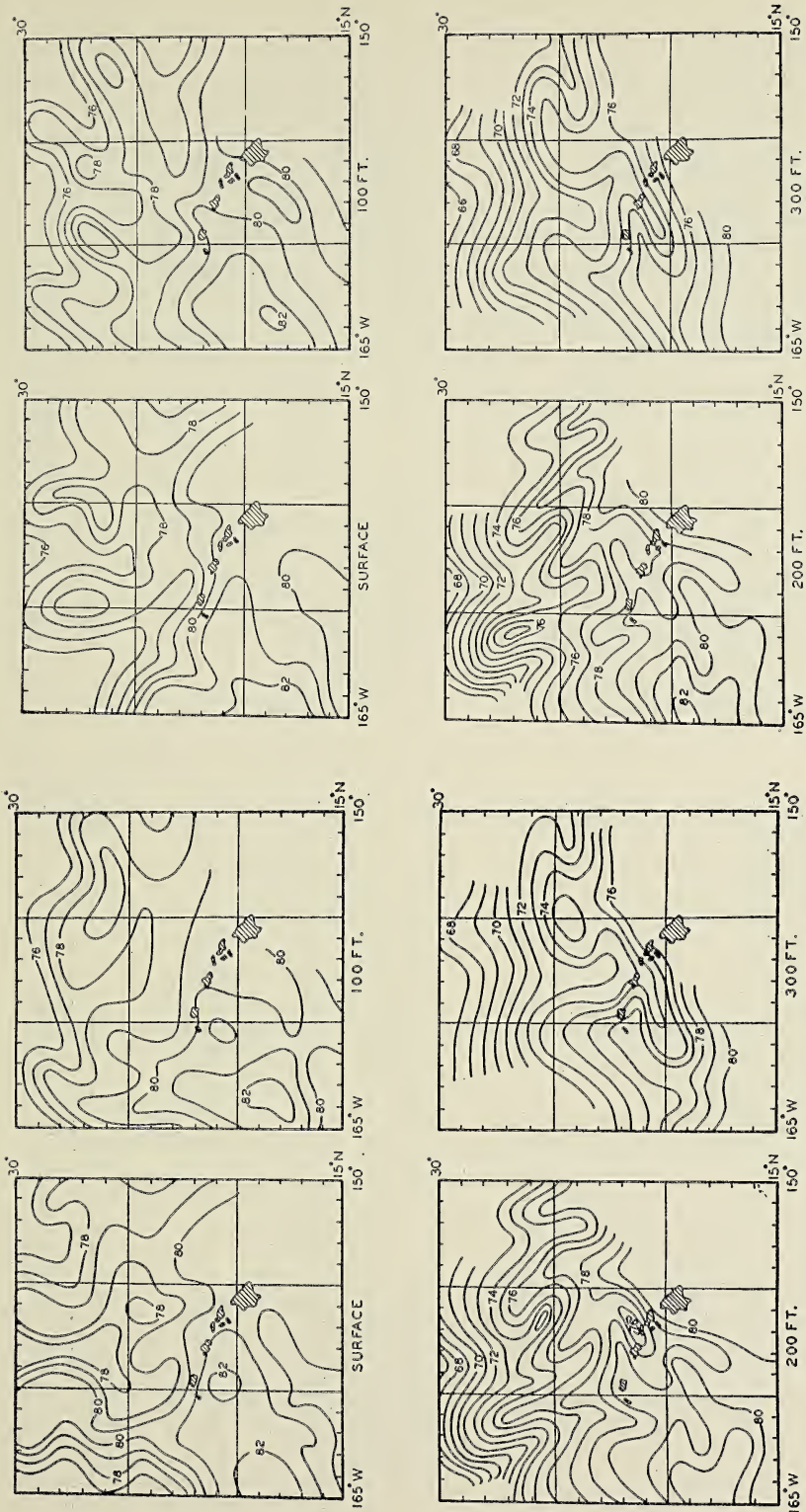


FIG. 10. SEPTEMBER, average sea temperatures (° F.) at selected depths (1941-1947).

FIG. 11. OCTOBER, average sea temperatures (° F.) at selected depths (1941-1947).

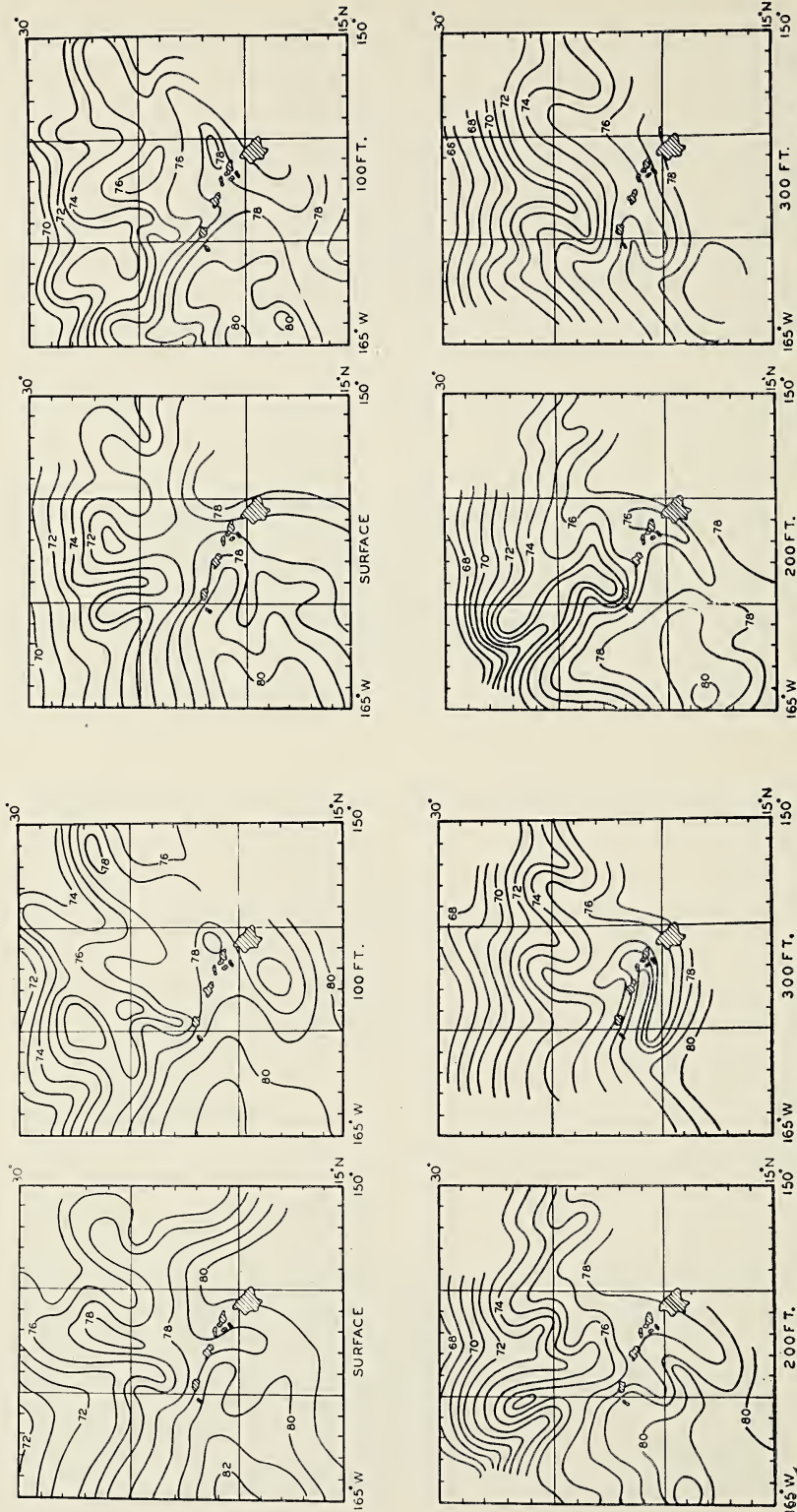


FIG. 12. NOVEMBER, average sea temperatures ( $^{\circ}$  F.) at selected depths (1941-1947).

FIG. 13. DECEMBER, average sea temperatures ( $^{\circ}$  F.) at selected depths (1941-1947).



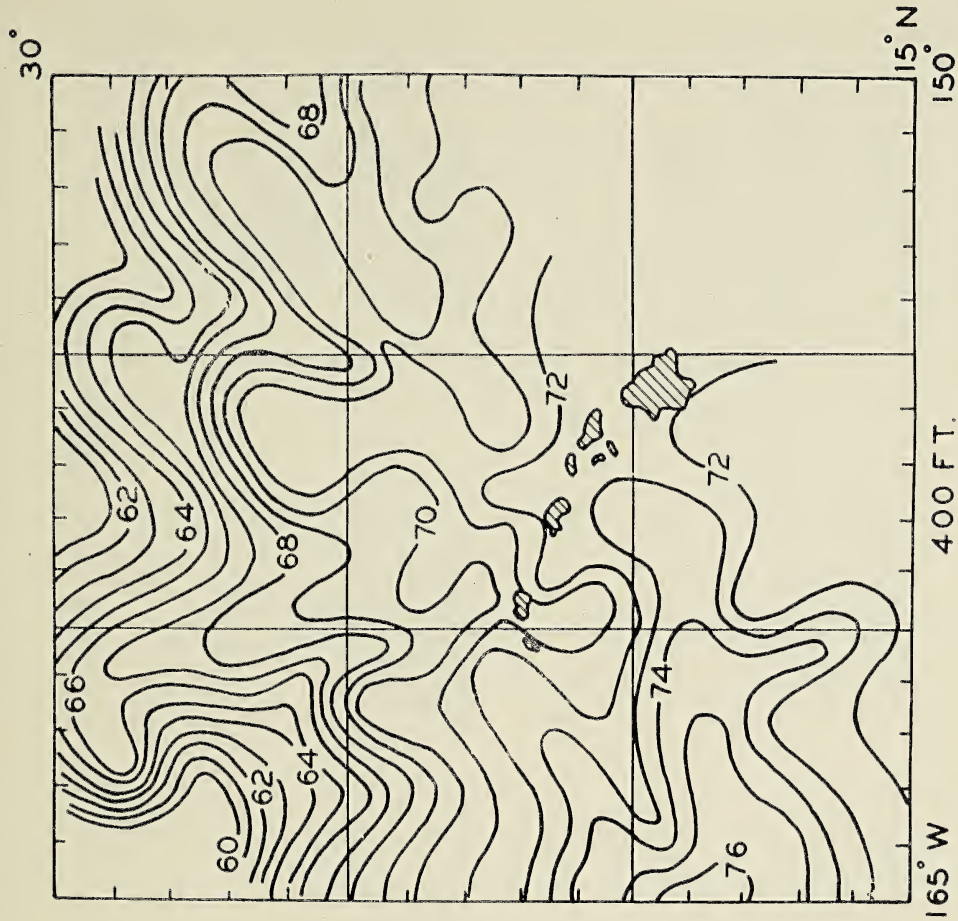


FIG. 15. Annual average sea temperatures (° F.) at 400 feet.

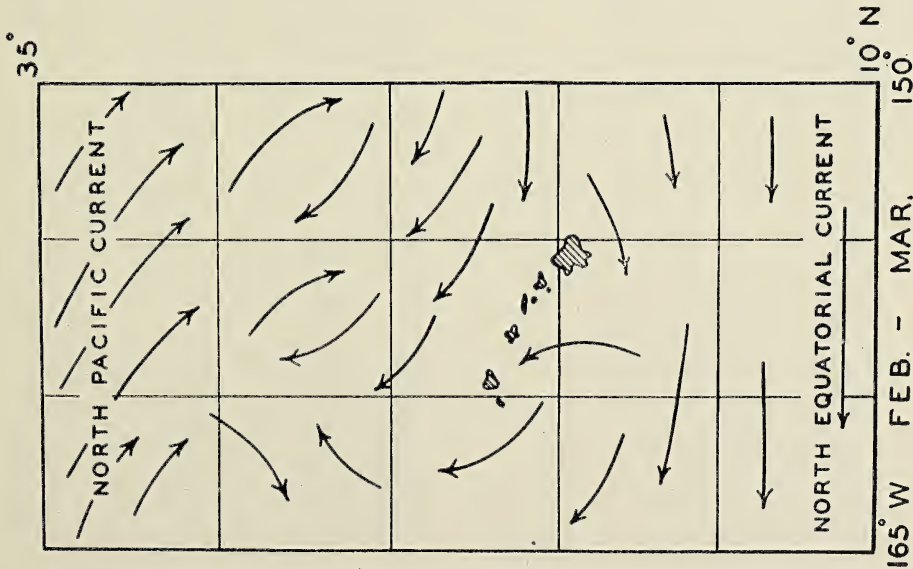


FIG. 14. Sketch of ocean currents; after Sverdrup.

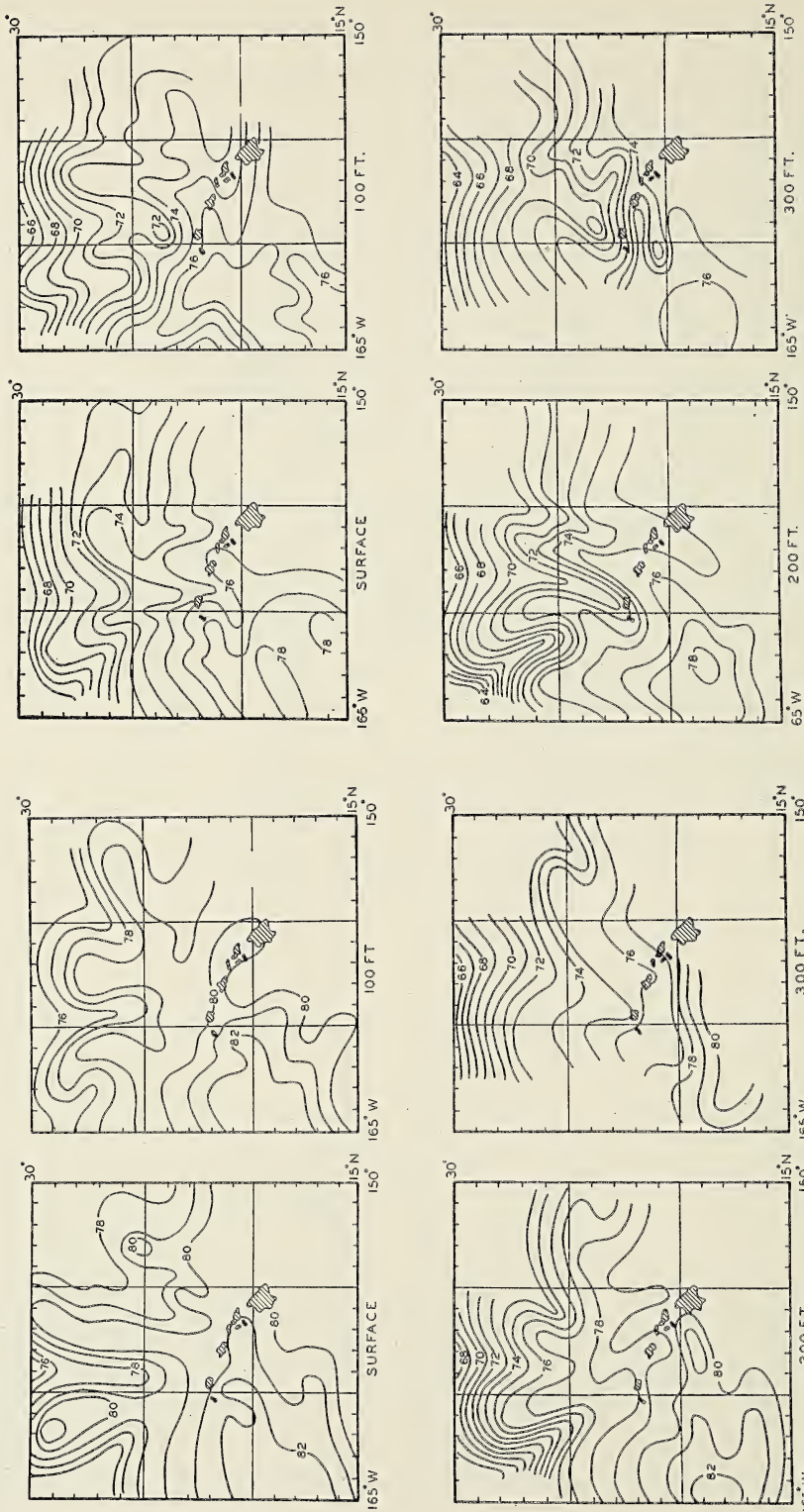
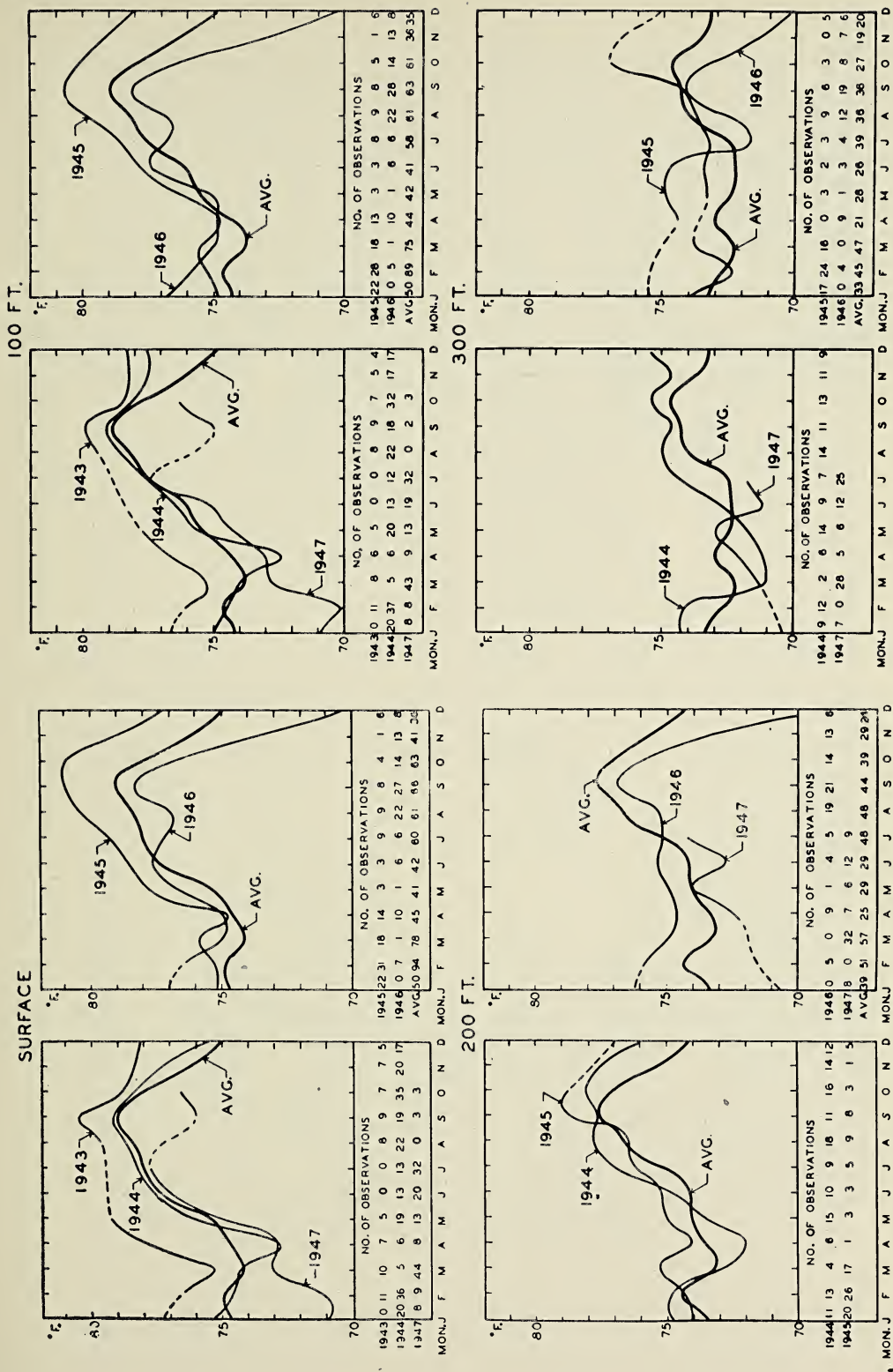


Fig. 16. Maximum monthly average sea temperatures (° F.), (1941-1947).

Fig. 17. Minimum monthly average sea temperatures (° F.), (1941-1947).





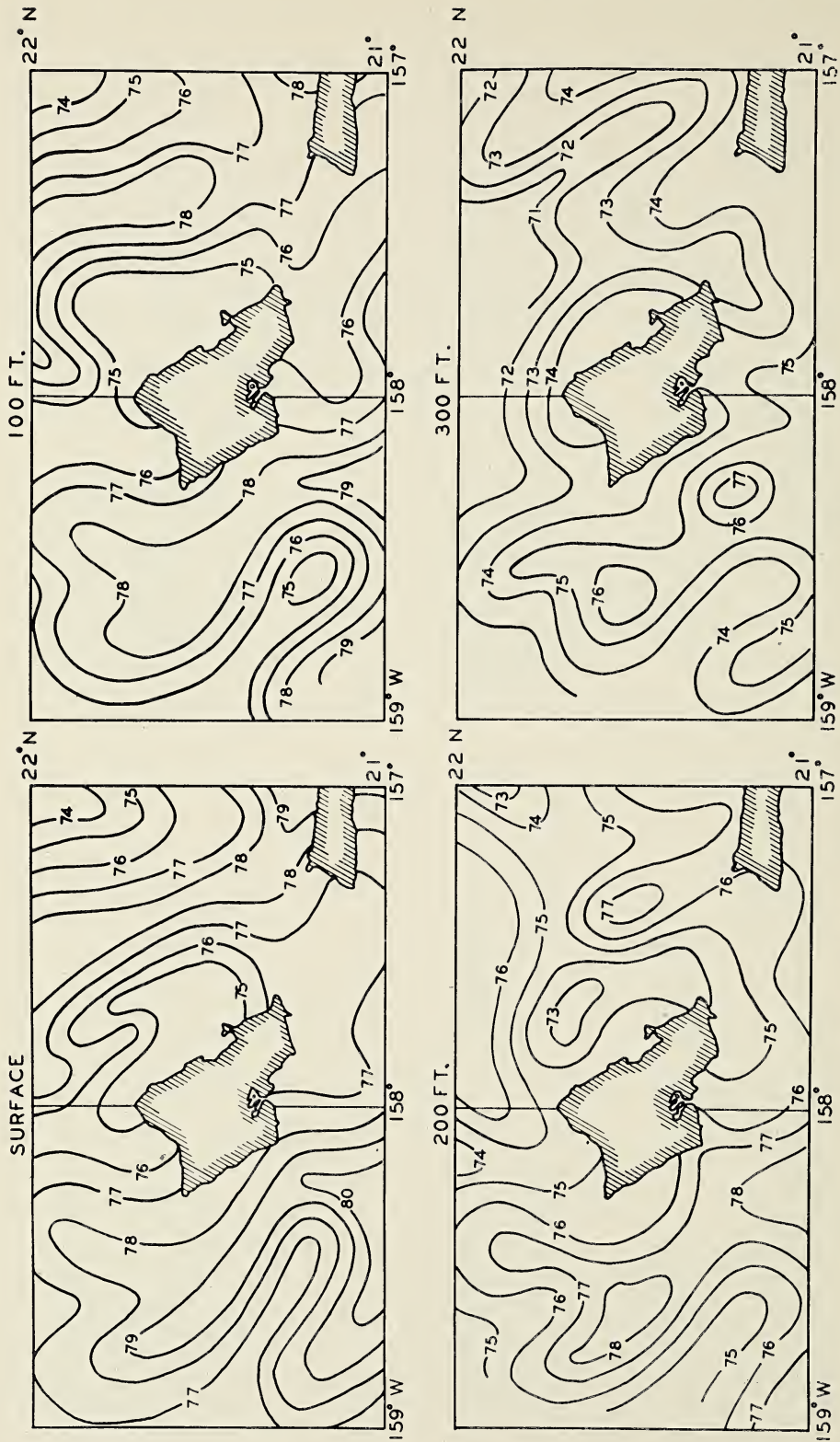


FIG. 19. Annual sea temperatures (° F.) in the vicinity of Oahu (1941-1947).



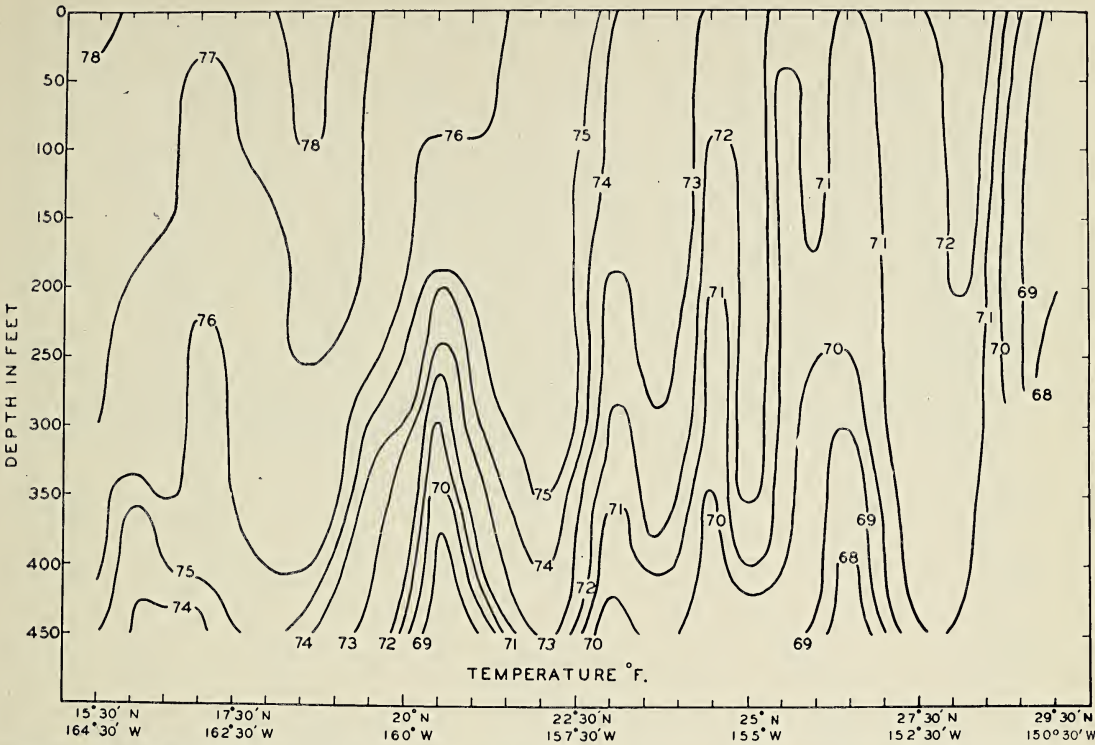


FIG. 20. SW-NE sea temperatures (° F.). Cross section (January, February, March, 1941-1947).

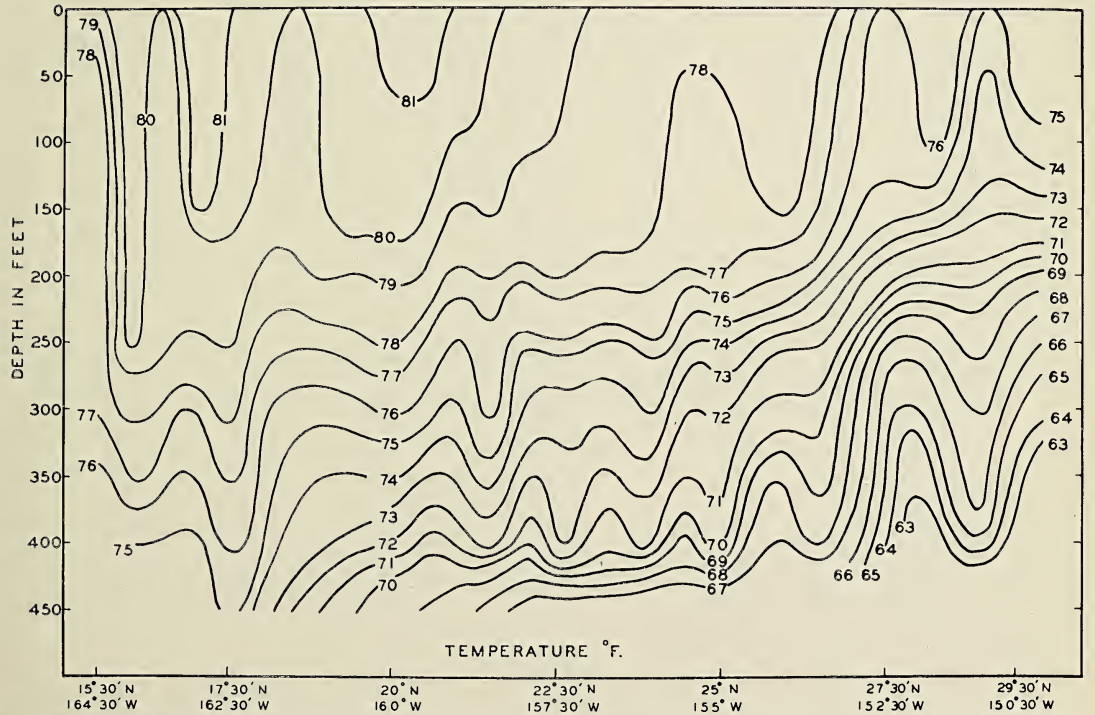


FIG. 21. SW-NE sea temperatures (° F.). Cross section (August, September, October, 1941-1947).

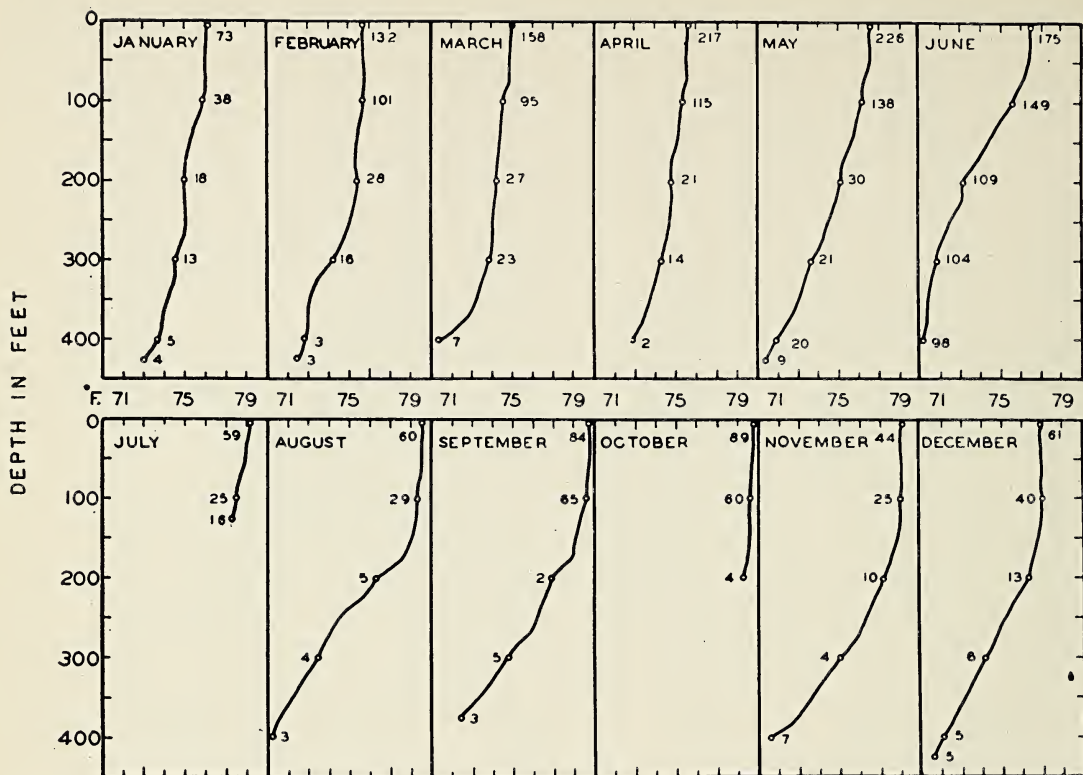


FIG. 22. Temperature depth curves; monthly averages (1941-1947); 20°-25° N, 155°-160° W.

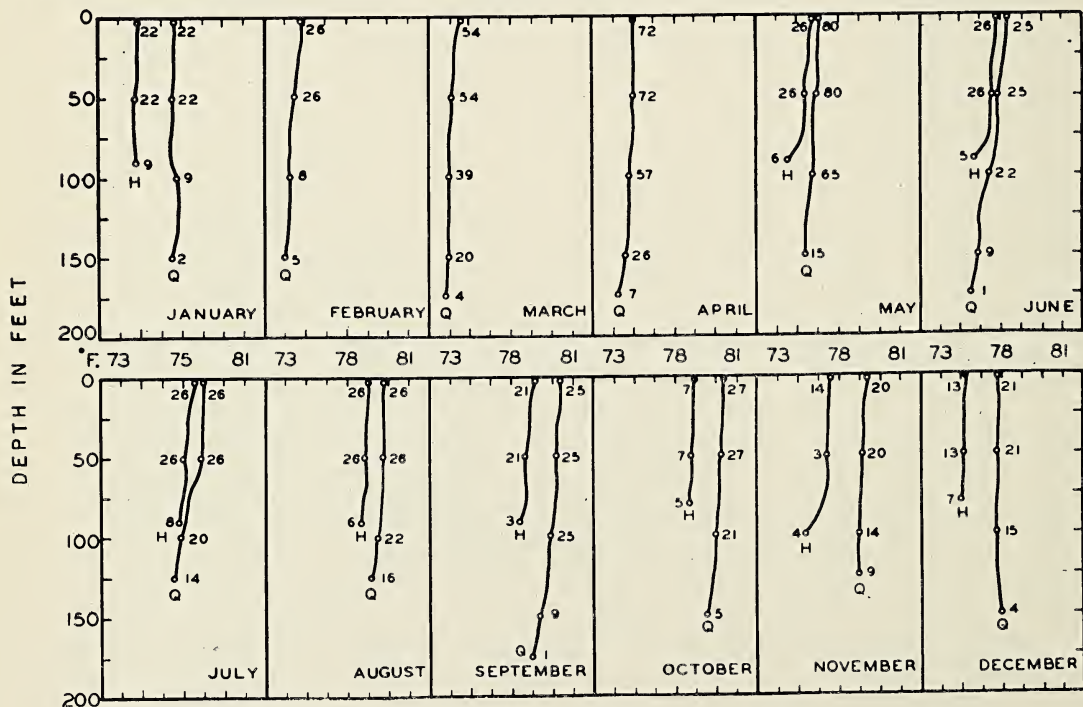
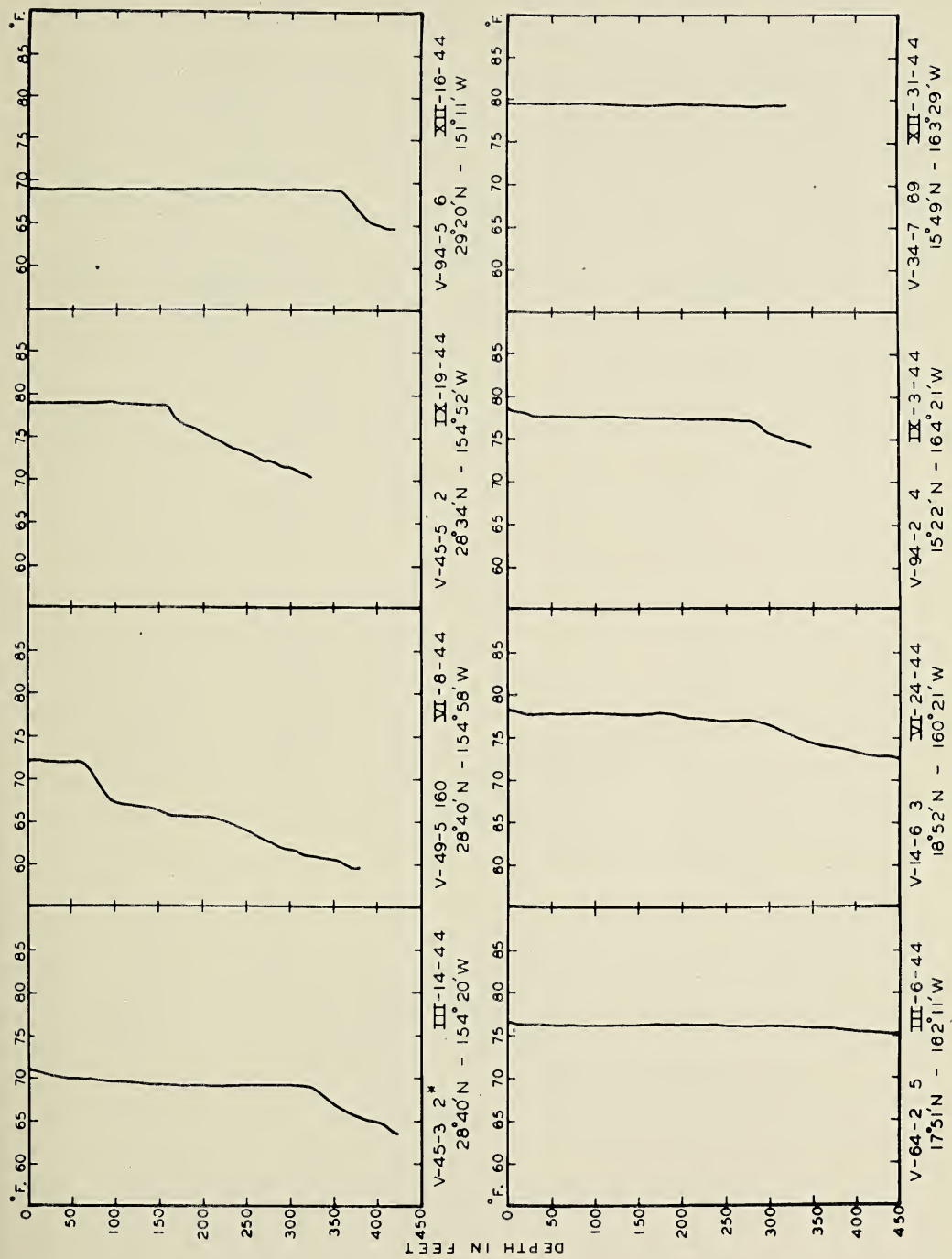


FIG. 23. Temperature depth curves; monthly averages. H cruises: March, 1944-February, 1945; 21° 18' N-157° 53' W. Q cruises: February, 1944-February, 1945; 21° 18' N-157° 53' W.





\* OBSERVATION NUMBER

FIG. 24. Typical bathythermograms for March, June, September, December. Upper row, northern portion. Lower row, southern portion.

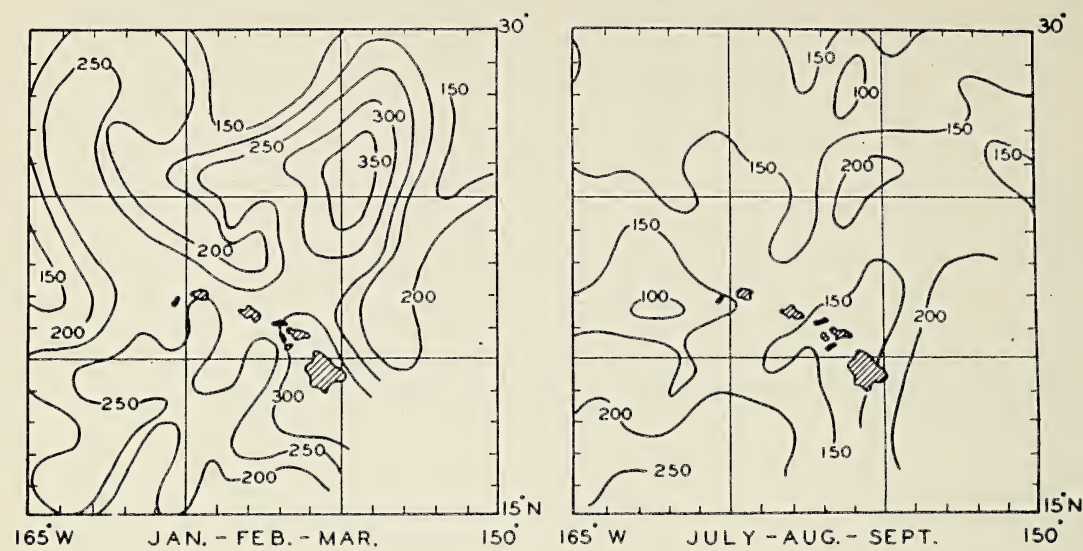


FIG. 25. Average depth of the virtually isothermal layer (1941-1947).

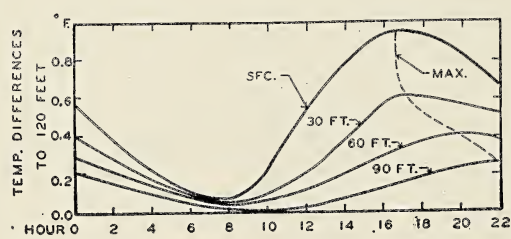


FIG. 26. Diurnal sea temperature variation (° F.); 21°-34° N, 138°-157° W.

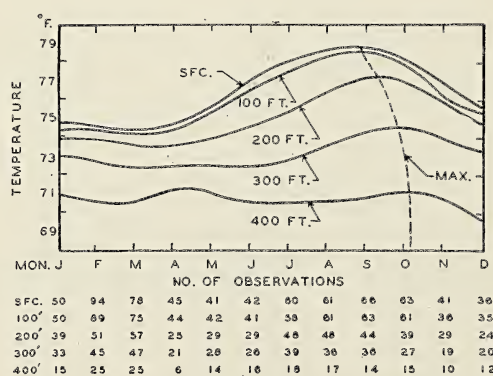


FIG. 27. Annual variation of temperature. 20°-25° N, 157°-160° W.



# A Taxonomic Revision of the Hawaiian Species of the Genus *Carex*<sup>1</sup>

ROBERT W. KRAUSS<sup>2</sup>

## INTRODUCTION

LINNAEUS PUBLISHED the genus *Carex* in *Genera Plantarum*, Ed. 1, p. 280, 1737, and again in *Genera Plantarum*, Ed. 5, p. 420, 1754. The present use of the name is based on the latter. The type species for the genus has been designated by Mackenzie (1923: 343) as *Carex acuta* var. *nigra* L., which has been known erroneously for some time as *Carex Goodenowii* J. Gay. Hitchcock and Green, however, have listed *Carex birta* L. in their list of Linnaean lectotypes (Camp, 1947: 114). The problem of typification is still an open one. The genus was recognized as a natural group even before the time of Linnaeus, but from 1754 to 1915 the group was included in different genera in accordance with various generic concepts, and also attempts were made to split the genus into segregates. Since 1754 a total of 55 generic names has been proposed for the genus or its segregates. Nevertheless, it is the consensus of present-day workers that the group, though large, deserves the unity of single generic rank.

In the Hawaiian Islands specimens of *Carex* have been regularly collected by botanists visiting the islands. The earliest collection examined for this study is that of James Macrae, which was secured on the island of Hawaii during the visit of H.M.S. "Blonde" in 1825. Since that date collections have been deposited in all the major herbaria in the world. In spite of the splendid collec-

tions which are available (approximately 600 numbers were received for this study), no monographic study of the Hawaiian carices has been made. From time to time species and varieties have been described from these islands, but often by botanists working far from Hawaii and who were using not only single specimens but often mere fragments of a plant.

Taxonomic differentiation within the genus rests fundamentally on the morphological differences in the achene and surrounding perigynium. The wide and distinct variation of these structures in such a vast number of species is remarkable. Identification of the species could be effected by reference to these structures alone. However, generic groupings which included species with similar perigynia but based on other characters—primarily on the arrangement of spikes and inflorescences—have been made. The use of such characters is indispensable in breaking the genus into smaller groups but the characters show much intergradation, and their use results in the placing together of seemingly unrelated species so that doubt is cast on their being natural groupings.

In applying the characters needed to delineate the Hawaiian species, certain considerations involving the nature of species and criteria for their erection or retention in the generic population represented in the islands must be discussed. The genus *Carex*, like many other genera, has been subjected both to extreme division into species and to conservative grouping in large polymorphic or perhaps aggregate species. An investigation to determine which treatment is nearer the truth is not the purpose of this study. The recent development of experimental methods

<sup>1</sup>A condensation of a research problem submitted in partial fulfillment of the requirements for the Master of Science degree at the University of Hawaii in the Department of Botany, June, 1949.

<sup>2</sup>Department of Botany, University of Hawaii. Manuscript received June 20, 1949.

in taxonomy is adding much valuable information to the field. No worker can afford to ignore this work. However, taxonomy has not yet reached a stage where these methods can be applied to all new populations coming into the ken of the scientist, though surely all added experimental work, both in genetics and ecology, will aid the taxonomist in interpreting the morphological differences he finds.

To evaluate a population and make it intelligible to other workers, a summary of definitions of the specific and subspecific categories is in order. The following definitions merely indicate the difficulty of determining the genotype of a specimen or population from the phenotype with which the taxonomist works.

*Biotypes* are relatively slight morphological variations within a constant genotype which vary at random and which reflect no differences in the genetic constitution of the plant. Almost every individual could be classed as a biotype.

*Forms* are groups of biotypes distinct from the other biotypes of similar genetic structure by one or more very slight morphological characters which are either determined or probable responses to a peculiar environment and may or may not indicate minor genetic differences.

*Varieties* are groups of biotypes or forms morphologically distinct from the normal biotypic range of the population, these variations being brought about by slight genetic differences and often subsequent isolation. Varieties in a population may interbreed on contact and show a degree of intergradation in morphological characters in some of the individuals.

*Species* are populations of one or more varieties, forms, and biotypes which are clearly distinct morphologically from all other related populations as a result of major genic differences. Interbreeding is usually restricted or impossible between related species though

certainly radical genetic morphological differences may occur in isolated species without loss of the ability to interbreed.

It is in no way intended to suggest that the above criteria are precise. In applying them to the populations of Hawaiian *Carex* it soon became apparent that both the biotypic and formal variation were much greater than has normally been allowed for species of this genus. In the case of *Carex wahuensis*, particularly, a tabulation technique was used giving all the possible visible or measurable characters by which species could be differentiated. Twenty of the most reliable characters used to differentiate *Carex* species were recorded for each of the specimens examined. The tabulation showed clearly that, in what at first appeared to be several distinct species, the gradations between supposedly distinct characters were so complete as to make impossible a delineation of more than one species. Only two minor characters in the perigynia (and these showing transitions with the typical) were found to be strong enough to be interpreted as of varietal worth. It is probable that even an able taxonomist confronted with a restricted number of specimens would have named several new species from among this group of specimens.

Examination of the work of Mackenzie on the North American carices has made very clear the seriousness of dividing into species populations which are little more than biotypes. An effort has been made here to be somewhat conservative in the erection and retention of species. In defense of this approach it may be said that the evidence strongly suggests extreme polymorphism in many of the groups. Though the species growing in the Hawaiian Islands may be distinct, the world population has other species of very close affinities to almost every one of them. These affinities are indicated in the discussion following each description. Not only does the very size of the genus suggest an extremely unstable and rapidly ramifying



genic structure, but the variations encountered in every species examined (see illustrations) have been considerable—not only in different individuals but in different sections of the inflorescence of the same individual. An effort has been made to keep intact the groups which form natural units, even though there is considerable variation within them.

*Acknowledgments:* Appreciation is due Dr. Harold St. John, Chairman of the Department of Botany, University of Hawaii, for guidance during the investigation. Miss Inger Achten is responsible for most of the illustrations, which add much to the usefulness of the work. I also wish to thank the directors of the various herbaria who lent material for the study. The cooperating institutions are listed under the Taxonomic Treatment. The effectiveness of the study is to a great degree the result of the work of many collectors.

#### DISTRIBUTION PATTERNS

The distribution of the genus is world-wide and the range of many species includes several continents. Not only have a vast number of species evolved in the genus but these species have become adapted to a very wide range in habitat as well. The majority are found in areas of more than average moisture but many survive in regions with sufficient rainfall to support grassland vegetation only. Certain of the Hawaiian carices do well in both wet forest and dry grassland, i.e., *Carex macloviana* D'Urv. and *Carex wahuensis* var. *rubiginosa* R. Krauss. Others in the islands are restricted to limited habitats; *Carex montis-eeka* Hillebd. and *Carex kauaiensis* R. Krauss are strictly high-bog plants.

Local distribution of the species and varieties is illustrated in the maps. The discussion following the species description gives the probable affinity and region of origin for each. In as many cases as possible the plants were compared with specimens collected in

the type locality in other parts of the world. The following tabulation indicates the geographic affinities of the Hawaiian species.

#### Japan and East Asia

- Carex Meyenii* Nees—Hawaiian endemic
- Carex wahuensis* var. *Meyeri* Franch. and Sav. (the type variety)—Hawaiian endemic
- Carex wahuensis* var. *rubiginosa*\* R. Krauss—variety, Hawaiian endemic

#### Australia

- Carex Nealae* R. Krauss—Hawaiian endemic

#### Pacific North America

- Carex macloviana* var. *subfusca* (W. Boott) Kükenth.
- Carex pluvia* R. Krauss—Hawaiian endemic
- Carex pluvia* var. *koolauensis*\* R. Krauss—Hawaiian endemic
- Carex alligata*\* F. Boott—Hawaiian endemic
- Carex alligata* var. *Degeneri*\* R. Krauss—Hawaiian endemic
- Carex kauaiensis*\* R. Krauss—Hawaiian endemic
- Carex Svenonis* Skottsdb.

#### Worldwide

- Carex montis-eeka* Hillebd.—Hawaiian endemic

\*These species and varieties are presumed to have originated in the islands from the ancestral stock of the species immediately above them.

Apparently original introductions of species to the Hawaiian Islands have come from all of the major land masses bordering the Pacific. Species found in the nearest archipelagos, however, are missing in Hawaii. Others from more distant land masses are well established here. The random origin from east, west, and south, and the limited number of species present, indicate infrequent establishment over long periods of time. It is the studied opinion of the author

that winds of hurricane force sweeping across the Pacific in different directions at different periods of geologic time are responsible for this random deposition. Certainly tremendous variations in climate have existed since the origin of the islands sometime in the early Tertiary period.

Speciation and distribution of the carices of Hawaii have not followed the usual pattern found in many island genera. There are only two narrow endemics—*Carex kauaiensis* R. Krauss, which is limited to the bogs of Kauai, and *Carex pluvia* var. *koolauensis* R. Krauss, which is found in the central Koolau Range on Oahu. The other species occur on most of the islands, though certain ones are conspicuously missing on the more westerly islands. There are no records of *Carex macloviana* var. *subfusca* (W. Boott) Kükenth., *Carex Svenonis* Skotts., or *Carex Nealae* R. Krauss on Oahu, Molokai, and Kauai. Hawaii and Maui, on the other hand, have every species and variety with the exception of *Carex kauaiensis* R. Krauss and *Carex pluvia* var. *koolauensis* R. Krauss. *Carex Meyenii* Nees, however, is the only species found on all the islands. The lack of local endemism is to be expected in a genus which fruits prolifically and is dispersed easily by air and water. Most of the species and varieties are able to survive on ridges as well as in ravines, so that geographical isolation of minor mutations does not occur often enough to be a factor in the development of taxonomic entities. Nevertheless, there appears to be some difficulty in achieving dispersal across the channels of water separating the islands. It is to be expected that a complete distribution will be achieved naturally in the future inasmuch as suitable habitats exist on all the islands for almost all of the species. The range of *Carex wahuensis* var. *rubiginosa* R. Krauss, which is moving into the region occupied by variety *Meyeri*, by migration from east to west, illustrates the path of such invasions although

the habitat range for this species is considerably greater than that for some of the others.

#### TAXONOMIC TREATMENT

This section presents a key to and descriptions of the species of *Carex* found in the Hawaiian Islands. The key is based on characters found in the mature-fruited inflorescence. The key may be followed using perigynia alone but, wherever feasible, additional characters of inflorescence and vegetative structure are included. The key is strictly an artificial one and no implications as to natural relationship are to be drawn from it. The distribution of the species may be more readily perceived by reference to the maps. The citations of specimens examined are followed by letters designating the herbarium in which they are found. These abbreviations follow the system proposed by Lanjouw (1939: 142). If no abbreviation is included, the specimens are in the Herbarium of the Bernice P. Bishop Museum, Honolulu, T. H. The abbreviations and the institutions in whose herbaria the specimens are deposited are as follows:

- C—Cornell University, Ithaca, New York
- GB—The Botanical Garden, Gothenburg, Sweden
- G—Conservatoire et Jardin Botanique, Geneva, Switzerland
- GH—Gray Herbarium, Harvard University, Cambridge, Massachusetts
- K—Kew Botanical Gardens, England
- KY—University of Kyoto, Japan
- NY—New York Botanical Garden, New York
- P—Museum National d'Histoire Naturelle de Paris, France
- US—Smithsonian Institution, Washington, D. C.
- TI—University of Tokyo, Japan

The illustrations have been selected to show the range of variation within each species and variety. Three different specimens



are illustrated for each species and two for each variety.

The maps are provided with legends explaining the symbols used. Where a symbol is half-shaded the location is considered only approximate. Only those locations which could reasonably be assigned to an area as small as 1 square mile are plotted.

KEY TO HAWAIIAN *Carex*

- 1. Perigynium trigonal to napiform;  
achene with a single, invaginate  
furrow at the equator . . . . . 2  
Perigynium trigonal to lenticular;  
achene with no furrow at the  
equator . . . . . 3
- 2. Teeth of bidentate beak over 1 mm.  
in length; beak and perigynium  
chartaceous, green, yellow, brown,  
not red-waxy . . . . .  
    *C. wahuensis* var. *Meyeri* (p. 254)  
Teeth of bidentate beak under 1 mm.  
in length; beak or entire perigy-  
nium red-waxy . . . . .  
    *C. wahuensis* var. *rubiginosa* (p. 257)
- 3. Stigmas 3; leaves stiff, erect, strong-  
ly involute or awl-shaped . . . . . 4  
Stigmas 2; leaves flexuous, not nor-  
mally involute or awl-shaped . . . . . 5
- 4. Mature plants over 15 cm. tall;  
spikes with more than 10 ach-  
enes; not dwarfed; leaves clearly  
involute . . . . .  
    . . . . . *C. montis-eeka* (p. 260)  
Mature plants under 15 cm. tall;  
spikes with fewer than 10 ach-  
enes; dwarfed; leaves awl-shaped  
    . . . . . *C. montis-eeka* f. *filifolia* (p. 262)
- 5. Perigynium multinerved, more than  
four nerves per side . . . . . 6  
Perigynium at most three-nerved on  
a side or not nerved . . . . . 9
- 6. Perigynium invaginate at the base,  
cordate; not stipitate . . . . .  
    . . . . . *C. Svenonis* (p. 263)
- Perigynium not invaginate at the  
base; stipitate . . . . . 7
- 7. Perigynium concave-convex, spindle-  
shaped, winged, non-glandular;  
beak strongly bidentate . . . . .  
    . . . . . *C. Meyenii* (p. 264)  
Perigynium bi-convex, not winged;  
beak narrow, entire or subentire . . . . . 8
- 8. Bracts strongly emarginate; perigy-  
nium ovate, strongly nerved, min-  
utely glandular, not purple-black;  
spikes gynaeandrous . . . . .  
    . . . . . *C. Nealae* (p. 267)  
Bracts acute to aristate, never emar-  
ginate, perigynium splotted with  
purple-black, not glandular, weak-  
ly nerved; spikes androgynous . . . . .  
    . . . . . *C. alligata* var. *Degeneri* (p. 278)
- 9. Perigynium winged, concave-convex;  
rostrum indistinct, tapering into  
the base of the perigynium; spikes  
short, forming a semiglobose ter-  
minal head 3 cm. in diameter or  
less . . . . .  
    *C. macloviana* var. *subfusca* (p. 269)  
Perigynium not winged, bi-convex;  
beak distinct; spikes separate, over  
3 cm. long, pendulant or erect,  
forming a branching inflorescence . . . . . 10
- 10. Perigynium light brown or green,  
dull chartaceous to membranous . . . . .  
    . . . . . *C. pluvia* (p. 271)  
Perigynium black or brown, highly  
polished, indurate . . . . . 11
- 11. Perigynium brown or yellow-brown,  
lenticular; one nerve on one side  
raised to give a trigonal aspect . . . . .  
    . . . . . *C. alligata* (p. 275)  
Perigynium black or purple-black;  
broad spindle-shaped, not nerved . . . . . 12
- 12. Perigynium not tightly packed in  
the spike, rachis visible, achene  
triangular in cross section, perigy-  
nia not stipitate . . . . .  
    . . . . . *C. kauaiensis* (p. 279)

Perigynium tightly packed in the spike, rachis not visible, achene lenticular, perigynia stipitate . . .

. *C. pluvia* var. *koolauensis* (p. 274)

*Carex wahuensis* C. A. Meyer var. *Meyeri* Franchet and Savatier, Enum. Plant. Japon. 563, 1879.

Figs. 1a-c, 2

*Carex wahuensis* C. A. Meyer, Acad. St. Petersb., Mem. 1:218, Tab. 10, 1831.

*Carex Boottiana* Hooker and Arnott, Bot. Beech. Voy., 273, 1841.

*Carex nupitalis* Boott, Illust. Genus Carex 4, 175, pl. 591, 1867.

Rootstocks caespitose forming dense clumps to 50 cm. in diameter; basal scales 0.5–1.5 cm. wide, 1.4–4 cm. long, 4–8 per culm, soon becoming loose, fibrillose, dark brown; fertile culm 2–4 mm. wide, 15–100 cm. long, isosceles triangular in cross section, lightly scabrous or smooth on the main veins and angles, erect, heads nodding; leaves 2–15, usually 6–7, mm. wide, 5–10 cm. long, 5–8 per culm, erect for about one-third the length, scabrous and toothed on all main veins on the underside, glabrous above, shiny, dark green to yellow; sheaths loose, dark brown to reddish, closed by a dark membrane extending 4–8 cm. above the rootstock, splitting along the membrane at maturity; inflorescence 4–25 cm. long, branching, 1–4 unbranched spikes arising from a node, 2–15 nodes per culm, internodes 2–6 cm. long at the base shortening toward the apex, each node and peduncle enclosed by the base of a leafy bract; spikes 0.5–1.5 wide, 2–10 cm. long above the peduncle, androgynous except the terminal one at each node which may be entirely staminate, 1 to 3 spikes at a node enclosed by leafy bract, peduncles 2–5 cm. long, enclosed at the base by an ochrea 10–15 mm. long; pistillate bracts ovate, truncate at the base, 2–3 mm. wide, 2.5–5 mm. long, awned, hyaline on margins, red or brown membranous in the center, keeled, awns 2.5–

5 mm. long, awl-shaped, toothed on margins; staminate bracts 2–5 mm. long, hyaline, keeled, awns 2–4 mm. long, toothed; perigynia 2–3.5 mm. wide, 3–8 mm. long, with

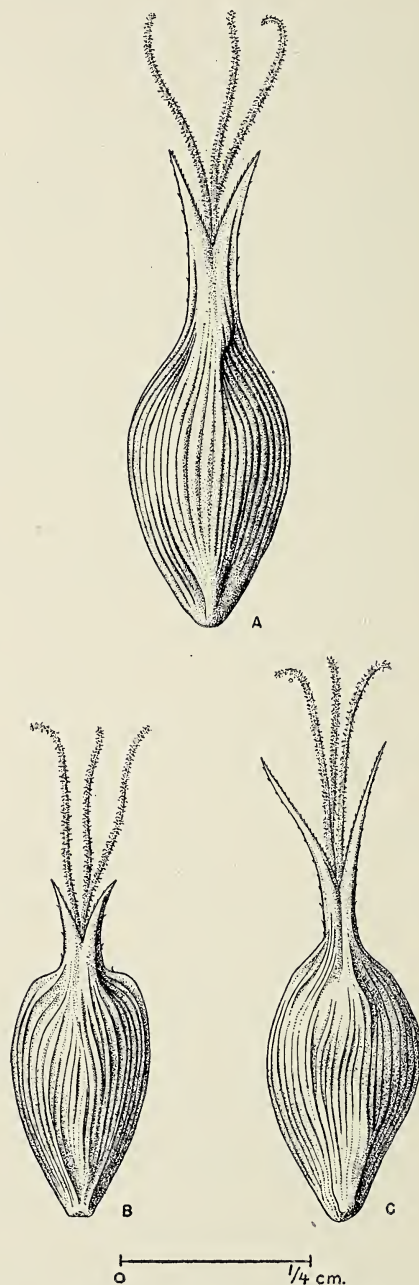


FIG. 1. Perigynia of *Carex wahuensis* C. A. Meyer var. *Meyeri* Franch. and Sav. a, Krauss 161; b, Hitchcock 15327; c, Christophersen 3695.



body obovoid, rarely bluntly stipitate though this condition not shown in the illustration; 20–30 nerved on a side, dull chartaceous, green to yellow or brown, rostrum 1–4 mm. long, minutely toothed on the upper third, bidentate, two teeth 0.9 mm. to 3 mm. long, spreading subulate; achene a double three-sided pyramid, distorted, invaginate at the middle or equator more strongly on one side, ridged on the angles, the planes slightly convex or concave, beak usually bent, 0.5–1 mm. long; style 1–2 mm. long, rising at right angles or less from the beak, dividing into three stigmas 2–3 mm. long.

*Distribution:* On all islands in Zone D of Ripperton and Hosaka (1942) in the middle forest zone in shade or on open ridges in full sun, on soil or damp rocky ravine walls.

*Type:* Illustrated by C. A. Meyer (1831: Table 10). The type specimen is deposited in the herbarium at Leningrad.

*Specimens examined*

KAUAI: *Degener* 2214, Olokele Canyon, July 3, 1926, (NY); *Degener* 2207, Hana-

pepe Falls, June 19, 1926, (NY); *Degener* 2205, NE of Kipu, June 17, 1926, (NY); *Fagerlind & Skottsberg* 6567, Kokee near stream opposite Phillip Rice's summer house, Mar. 12, 1948 (GB); *Heller* 2849, on Kaholuamanoa above Waimea, Oct. 1–8, 1895 (K, US); *Hitchcock* 15327, Kaholuamanu, 3500', Oct. 20, 1916 (US); *MacDaniels* 723, Haupu, 300 m., Feb. 16, 1927; *Nuttall*, Attooi [= Kauai] (K); *St. John* 10893, Maunapulo, Hanakapiai, Napali Coast, Dec. 30, 1930; *St. John* 10817, Nualolo Trail, 2900', Dec. 28, 1930; *St. John* 13619, Kipu, 1100', Dec. 25, 1933; *St. John* 23087, Olokele Ditch Trail, 2 mi. below Ditch House, Dec. 26, 1947; *St. John* 23142, rocky base of cliff, Waiahuakua Valley, 1500', Dec. 29, 1947; *St. John* 22880, Waimea Trail, Kokee, 3700', Dec. 21, 1947; *St. John* 23194, West branch of Hanakoa Valley, 1000', Dec. 31, 1947; *St. John* 23078, Olokele Ditch Trail, 1427', Dec. 26, 1947; *St. John & Fosberg* 13717, Milolii Ridge, 1600', Dec. 27, 1933; *St. John & Fosberg* 13718, Milolii Ridge, 2000', Dec. 27, 1933; *Skottsberg* 1043, Olo-

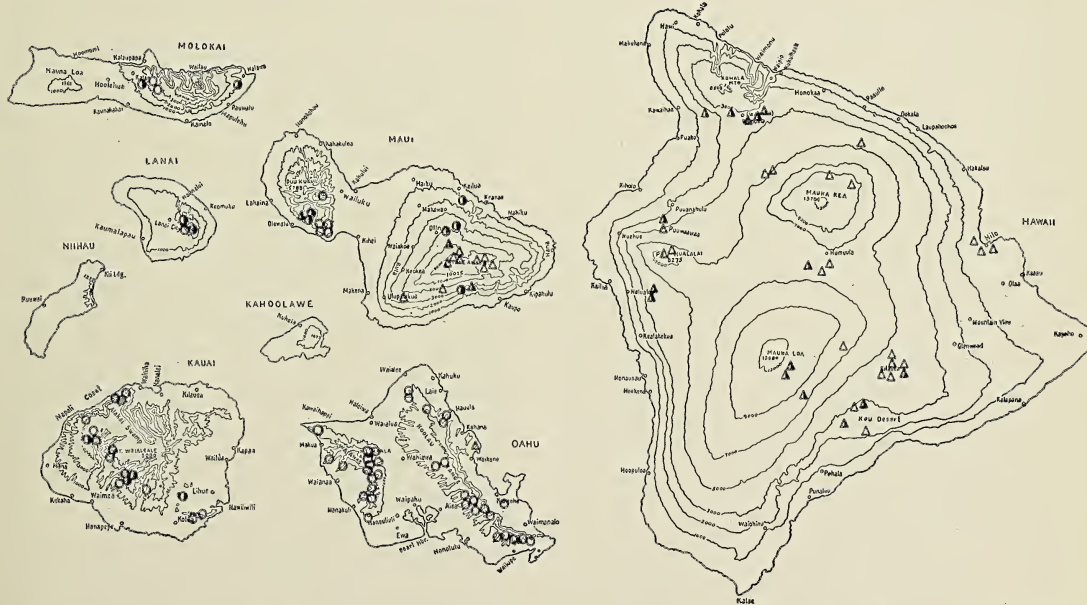


FIG. 2. Distribution of *Carex wahuensis* C. A. Meyer var. *Meyeri* Franch. and Sav. (indicated by circles) and of *C. wahuensis* C. A. Meyer var. *rubiginosa* R. Krauss (indicated by triangles).

kele Canyon, Oct. 21, 1922; *Smith, Whiting, Neal*, Kokee, 3500', May 1, 1929.

OAHU: *Bryan* 706, Mt. Kaala, 900 m., Apr. 21, 1929; *Christophersen* 3677, below Kanehoa, 400 m., June 1, 1932; *Christophersen* 3695, below Kanehoa, 350 m., June 1, 1932; *Christophersen, Wilder, Hume* 1526, Kuliouou, 450-600 m., Feb. 5, 1931; *Christophersen, Wilder, Hume* 1549, below Puu Kapu, 350-500 m., Feb. 12, 1931; *Cowan* 851,  $\frac{1}{4}$  mi. N of Puu Kaua, Feb. 29, 1948; *Cowan* 955, Halawa Ridge Trail, Apr. 25, 1948; *Cowan* 814, ridge trail to Palikea, Feb. 4, 1948; *Degener* 8272, head of Kuliouou Valley, Dec. 11, 1927, (NY); *Degener* 8218, small valley E of Palikea, Oct. 23, 1932, (NY); *Degener* 5268, Kolekole Pass, May 1, 1926, (NY); *Degener* 8220, top of Kaena Pt., Jan. 31, 1932, (NY); *Degener* 8221, Pupukea, Kahuku Trail, Pupukea side, Mar. 30, 1927, (NY); *Degener* 8281, near summit of Kaala, Feb. 11, 1928, (NY); *Degener* 5263, E ridge of Manoa Valley, Feb. 6, 1927, (NY); *Degener* 8219, first gully S side of Keaau Valley, Feb. 7, 1932, (NY); *Degener* 19581, Mokuleia mauka, 2000', May 2, 1949; *Fagerlind* 6459, trail to Puu Kaua, Feb. 29, 1948, (GB); *Forbes* 1471.0, Lanihuli Trail, Mar. 15, 1910; *Forbes* 2518.0, Waialae Valley, Jan. 8, 1919; *Forbes* 2425.0, Waialae iki, Feb. 28, 1917; *Forbes* 2466.0, ridge between Niu and Wailupe, Apr. 11, 1917; *Forbes* 2523.0, Wailupe, Jan. 1919; *Fosberg* 13552, Kailua, Ulumawao, 130 m., Jan. 24, 1937; *Fosberg* 12281, Nuuanu Pali, 370 m., Oct. 14, 1935; *Fosberg* 9273, Palolo Valley, 425 m., Mar. 19, 1933; *Fosberg* 13799, Nanakuli Valley Head, 825 m., May 2, 1937; *Fosberg* 13007, Puu Kalena, 930 m., Mar. 22, 1936; *Heller* 2389, lower slopes of Waiolani, June 6, 1895; *Hillebrand* 560, Nuuanu Valley, 1860-67; *Hitchcock* 13788, Nuuanu Pali, June 17, 1916; *Hitchcock* 14049, Nuuanu Pali, July 19, 1916; *Hosaka* 540, Kipapa, 1000', May 15, 1932; *Hosaka* 948, Kipapa Gulch 1800',

Mar. 19, 1933; *Hume* 482, Puu Kanehoa, 1500', Jan. 18, 1932; *Krauss* 183, SE slope of Kaala, 3000', Apr. 18, 1948; *Krauss* 247, trail along Wiliwilinui ridge, 1450', June 28, 1948; *Krauss* 243, trail along Wiliwilinui ridge, 1300', June 28, 1948; *Krauss* 126, trail to Puu Kaua, 2800', Feb. 29, 1948; *Krauss* 123, trail to Puu Kaua, 3000', Feb. 29, 1948; *Krauss* 121, trail to Puu Kaua, 3000', Feb. 29, 1948; *Krauss* 140, ridge S of Maakua Gulch, 800', Mar. 21, 1948; *Krauss* 161, Palikea, 2800', Mar. 26, 1948; *Krauss* 114, Palikea, Feb. 4, 1948; *Krauss* 109, Palikea, Feb. 4, 1948; *Krauss* 108, Palikea, Feb. 4, 1948; *Krauss* 188, Kaala, 3000', Apr. 18, 1948; *Krauss* 196, Kaala, 2000', Apr. 18, 1948; *Krauss* 197, Kaala, 2000', Apr. 18, 1948; *Krauss* 198, Kaala, 3000', Apr. 18, 1948; *Krauss* 199, Kaala, 2500', Apr. 18, 1948; *Krauss* 111, Palikea, 3000', Feb. 4, 1948; *Krauss* 140, ridge of Maakua, 600', Mar. 21, 1948; *Krauss* 561, N fork of Elehaha Stream, 865', Apr. 16, 1949; *Nuttall*, Oahu, (K); *Remy* 142, Oahu, 1851-55, (GH, P); *St. John* 10440, Puu Hapapa, Waianae Mts., 2800', Mar. 16, 1930; *St. John* 21569, Waimanalo, 750', Mar. 24, 1946; *St. John* 10385, Palikea, 1200', Feb. 23, 1930; *St. John* 17612, Puu Kawiwi, 2800', Mar. 31, 1935; *St. John* 20182, Kaluanui Ridge, 1500', Feb. 16, 1941; *St. John* 13154, Pohakea Pass, 2100', May 12, 1933; *St. John* 10441, Puu Hapapa, 1700', Mar. 16, 1930; *St. John* 14059, E of Puu Kanehoa, 2350', Jan. 7, 1934; *St. John* 13047, Laie-Malaekahana ridge, 1100', Apr. 15, 1933; *St. John* 11044, Puu Kanehoa, 2700', Mar. 22, 1931; *St. John* 14018, Puu Kanehoa, 2700', Jan. 7, 1934; *St. John* 13037, Kalauao ridge, 1500', Mar. 29, 1933; *St. John* 11069, Puu Kanehoa, 2000', Apr. 22, 1931.

MOLOKAI: *Degener* 8239, ravine NW of Mauna hui, May 27, 1928; *Degener* 8238, Kahuaawi Gulch, May 12, 1928; *Degener*, 8230, ravine, S of Mauna hui cabin, Apr. 15,



1928; *Fagerlind & Skottsberg* 6376, along road from Mapulehu to Halawa, E coast, Feb. 20, 1948, (G).

LANAI: *Fagerlind & Skottsberg* 6418, W side of main ridge near Munro's old place, Feb. 24, 1948, (G); *Hitchcock* 14690, ravine at foot of mountain, Sept. 21, 1916, (US); *Munro* 408, Pohaku, Feb. 27, 1915, (US); *Munro* 297, Kaiholena, Feb. 17, 1914; *St. John & Cowan* 22609, SW ridge of Kaiholena Gulch, Kamoku, 2300', Apr. 4, 1947; *St. John & Cowan* 22612, SW ridge of Kaiholena Gulch, Kamoku, 2200', Apr. 4, 1947.

MAUI: *Degener* 8244, Manawainui Gulch near Puu Anu, dry side, July 12, 1927, (NY); *Degener* 8243, Manawainui Gulch near Puu Anu, dry side, July 12, 1927, (NY); *Degener* 8246, ridge N of Popakea Gulch, July 23, 1927, (NY); *Degener* 8254, hill mauka of Olinda, June 15, 1927, (NY); *Degener* 8247, ridge N of Popakea Gulch, July 23, 1927, (NY); *Degener* 8249, along pipe-line trail, Olinda, June 22, 1927, (NY); *Forbes* 2338.M, Olowalu Valley, May 2, 1920; *Forbes* 2285.M, Olowalu Valley, May 9, 1920; *Forbes* 2339.M, Olowalu Valley, May 12, 1920; *Forbes* 1862.M, Waiopaa Ranch, Nu'u, Mar. 6, 1920; *Remy* 143, Maui, 1851-55, (P); *Rock* 8747M, Makaima, Apr. 1911; *Rock* 8753M, shore at Nahiku, May 10, 1911; *St. John* 10280, Iao Valley, 1200', Feb. 9, 1930.

HAWAII: *Spach*, Owhyhee, Jan. 1859, (K).

SANDWICH ISLANDS: *Hillebrand* (Erroneously as Hillebrant) 2328, Sandwich Islands, 1860-67, (US), (immature).

*Carex wahuensis* C. A. Meyer is a member of the subgenus *Eucarex* Coss. & Germ. (Kükenthal, 1909: 293) section *Rhomboidales* Kükenth. (Kükenthal, 1909: 622). It is easily distinguished from the other Hawaiian species by the deep groove in the achene. Its apparent origin is in the western Pacific, the Hawaiian members being only slightly different from those of Japan. Names placed in synonymy were created by authors who

felt they could segregate new species or by those who received specimens from areas distant from Oahu and expected no similarity. These are *Carex Boottiana* Hooker and Arnott (Hooker, 1841: 273) collected from Japan, and *Carex nupitalis* Boott (Boott, 1855: 175) from Hawaii. Boott was misled by the distorted appearance of the immature fruit so clearly shown in his Plate 591. This plate is based on *Remy* 142 from Oahu and on a single spike from Nuttall's collection. Variety *Meyeri* of Franchet and Savatier was made after an examination of the species collected in the Hawaiian Islands and those from Japan and the Bonins. The variety *Meyeri* was apparently created from the material of Remy in order to have a contrasting variety to variety *robusta* from Japan and variety *Bongardii* from the Bonins. The only citation of the habitat of variety *Meyeri* is "ex speciminibus herbarii Mus. Parisiensis." Earlier in their discussion of the contrasting characters of the two varieties *robusta* and *Bongardii* as opposed to those in the species, they mention that they are compared to the plants collected by Remy in the Paris Herbarium. It is apparent that the intent of Franchet and Savatier was to make a variety corresponding to variety *typica* as now used. The International Rules, in Recommendation 18, specify that new names should not be used for the variety containing the type of the species but instead such names as *typicus*, *genuinus*, etc. The use of another name for the typical variety is not definitely prohibited, however. Therefore the variety *Meyeri* must be accepted as the variety of *Carex wahuensis* C. A. Meyer containing the original species.

The type specimen was not seen but C. B. Clarke (1904: 319) in his discussion of *Carex Wilfordii* C. B. Clarke says that the type corresponds well with Tab. 10 of Meyer. *Carex wahuensis* C. A. Meyer var. *rubiginosa* var. nov.

Figs. 2, 3a-d

A specie differt in utriculis 2.5-4 mm. latis,

3–8 mm. longis trigonis obovoideis aut obnapiformis valde multinervosis ad debilitibus nervosis, in rostris et prope omnis corporis

utriculis rubri-cereis, rostris 1.5–3 mm. longis bidentatis angustis, dentibus 0.15–0.9 mm. longis, — 0.9 mm. longis solum in exemplis grandissimis.

Similar to the species except in following characters: Perigynia 2.5–4 mm. wide, 3–8 mm. long, broad-obovoid to obnapiform tapering to a truncate base, roughly 3-angled strongly multi-nerved or obscurely several-nerved, bright red-waxy on rostrum and usually on most of the surface of the perigynium, rostrum bidentate, 1.5–3 mm. long, narrow, teeth 0.15–0.9 mm. long, approaching 0.9 only in very large individuals.

*Distribution:* On Hawaii, Maui, rarely Oahu, in Zones D and E of Ripperton and Hosaka (1942), in the upper forest in dry sunny cliff faces and open meadows, seldom in shade, usually over 4,000 feet.

*Type:* H. St. John, R. S. Bean, and E. Y. Hosaka 11228, Kilauea Iki, 3930' alt., Dec. 21, 1931.

#### *Specimens examined*

OAHU: St. John 11080, Kaaawa Valley, 800', Apr. 12, 1931.

MAUI: Degener 5262, Haleakala, (NY); Degener 8241, N of Ulupalakua, July 4, 1927, (NY); Degener 8250, Haleakala near Koolau Gap, June 29, 1927, (NY); Degener 8265, Koolau Gap, Haleakala Crater, Aug. 11, 1927, (NY); Degener 8270, Haleakala Crater, Aug. 9, 1927, (NY); Forbes 296.M, Haleakala, Aug. 1910; Forbes 698.M, NE of Ukulele, July 9, 1919; Forbes 1089.M, Haleakala Crater, Aug. 8, 1919; Forbes 2285.M, Olowalu Valley, May 9, 1920; Forbes 1876.M, Waiopaa Ranch, Mar. 6, 1920; Forbes 1887.M, Puu Pani, Mar. 8, 1920; Forbes 2104.M, Auwahi, S slope of Haleakala, Mar. 24, 1920; Forbes 2141.M, Puu Ouli, Haleakala, 4300', Apr. 4, 1920; Forbes 2143.M, Puu Ouli, Haleakala, 4300', Apr. 4, 1920; Fosberg 9928, Haleakala between bottomless pit and pali, 2150 m., Sept. 23, 1933; Hillebrand, Haleakala, (K); Hil-

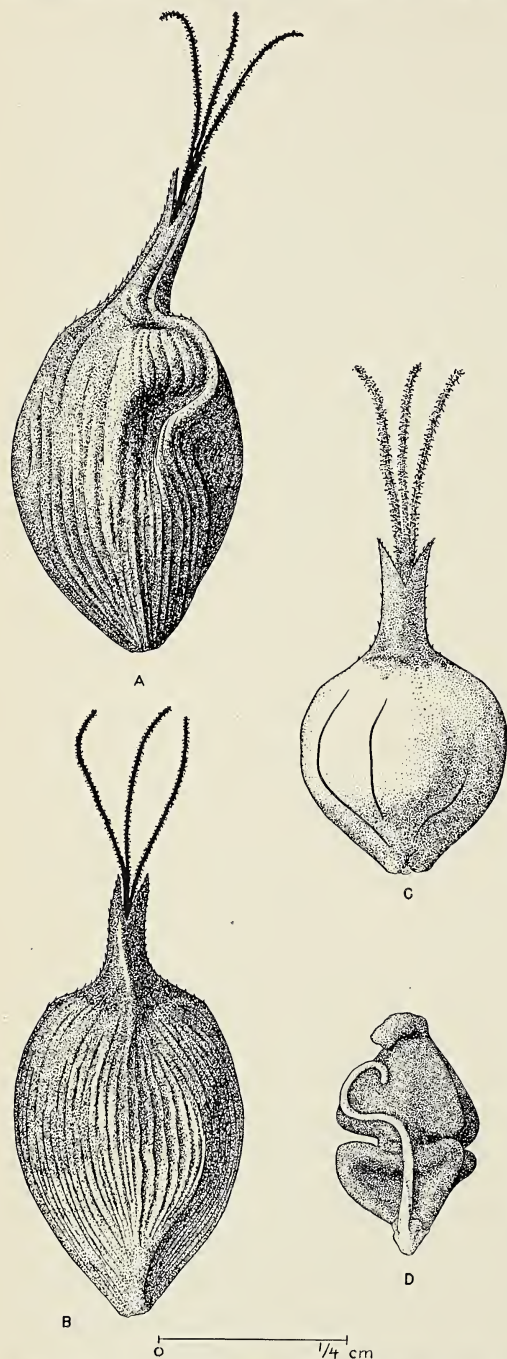


FIG. 3. *Carex wahuensis* C. A. Meyer var. *rubiginosa* R. Krauss. a–c, perigynia; d, achene. a, Degener 2218; b, Forbes 172.H; c, d, Krauss 348.



*lebrand* 531, Haleakala, 7000', (K); *Krauss* 346, cliffs above Holua, 7000', Sept. 3, 1948; *Krauss* 348, cliffs above Holua, 7000', Sept. 3, 1948; *Krauss* 349, cliffs above Holua, 7000', Sept. 3, 1948; *Krauss* 352, cliffs above Holua, 7000', Sept. 3, 1948; *Remy* 144, 1851–55, (P); *Rock* 8750, Haleakala, 8000', Apr. 20, 1911.

HAWAII: *Degener* 2218, E of Kilauea-iki, July 17, 1926, (NY); *Degener* 2217, 17 mi. from Kohala to Waimea, July 31, 1932, (NY); *Degener* 2215, between N Kona and Kau Desert, July 15, 1926, (NY); *Degener* 2219, W of Kilauea along Kau Rd., July 21, 1926, (NY); *Degener* H103, Haw. Nat'l Park, moist forest near Kilauea-Iki, Dec. 21, 1922, (NY); *Degener* 19262, Nenui, central plateau, Sept. 17, 1948, (NY); *Ewart* 326, Hanaipae, 5000', Feb. 14, 1934; *Fagerlind & Skottsberg* 6242, truck road between Kilauea and Mauna Loa, 6000', Feb. 2, 1948, (GB); *Faurie* 1214, shore of Hilo, May 1909, (G); *Forbes* 172.H, Hanehane, Kona, June 15, 1911; *Forbes* 914.H, Flow of 1880, Kipuka-ahui, June 23, 1915; *Forbes* 9039.H, Mauna Kea above Lai Niaia, June 18, 1915; *Fosberg* 10114, between Makaopuhi and Napau Craters, Kilauea, 890 m., Aug. 29, 1933; *Hillebrand* 1960, Hilo, (US); *Hillebrand* 532, Hilo, (K); *Hinds* 2, 1841, (K); *Hitchcock* 14433, Humuula Sheep Station, 6000', Aug. 27, 1916, (US); *Hitchcock* 14477, Puu Waawaa, Aug. 30, 1916, (US); *Hitchcock* 15592, Hualalai Mt. summit, Aug. 25, 1916, (US); *Hitchcock* 14224, Kukaiau Ranch, 3600', Aug. 20, 1916, (US); *Hitchcock* 14283, Mauna Kea, N side, 800–1000, Aug. 22, 1916, (US); *Judd*, Waikii, July 21, 1928; *Macrae*, Kaaha, June 1825, (K); *Mann & Brigham* 328, summit of Hualalai, 1867, (G); *Meebold*, Kipuka Puauulu, Kilauea, May 1932; *Neal & Hartt* 666, Base of Puu Hulukulu, 6610', Aug. 6, 1935; *Nuttall* 3, (K); *Remy* 145, 1851–55, (P); *Rock* 8741, Kilauea Volcano, Apr. 1911; *Rock* 8411, Waikii, June 1910; *Rock* 8742, Kilauea

Volcano, Apr. 1911; *Rock* 10042, Pulehualua, Jan. 1912; *St. John* 11333, Manuka Mauka, 1700', Dec. 26, 1931; *St. John, Bean, and Hosaka* 11228, (See Type); *St. John & Cowan* 22312, Halfway House, Kau Desert, 2900', Dec. 23, 1946; *St. John* 11220, chain of craters, Napau Trail, 2750', Dec. 30, 1931; *Skottsberg* 1103, between Kilauea and Kapapala, Sept. 18, 1922, (GB); *Skottsberg* 633, S slope of Hualalai, 1200 m., Sept. 23, 1922, (GB); *Skottsberg* 633b, Hualalai, 2000 m., Sept. 24, 1922, (GB); *Skottsberg* 1874, Kilauea Iki, Sept. 21, 1926; *Skottsberg* 517, E slope of Mauna Loa, Sept. 15, 1922; *Wilkes Exped.*, crater W Lua Pele, 1838–42, (US); *Wilkes Exped.*, district of Waimea, 1838–42, (US); *Wilkes Exped.*, Mauna Loa, 1838–42, (US); *Wilkes Exped.*, Mauna Loa, above 8000' station, 1838–42, (US).

SANDWICH ISLANDS: *Hillebrand* 2325, Sandwich Islands 1860–67, (US); *Hillebrand* 2327, Sandwich Islands 1860–67, (US).

*Carex wahuensis* Meyer var. *rubiginosa* is the only possible segregate in this species. A detailed tabulation, with careful measurements and repeated observations, was made of each specimen examined. It soon became apparent that the population was one of many different biotypes varying in stature as well as in floral structure. Every possible character was used to separate the plants into logical natural groups. Only two characters seemed usable and they were occasionally difficult to distinguish even to the trained eye. One is the red-waxy color of the perigynia of plants from Hawaii and Maui. The other is the very short teeth, usually only 0.5 mm. in length, of the beak of the perigynia. Other characters believed infallible in *Carex*—such as structure and shape of the perigynia, setaceousness of the rostra, and complexity of inflorescence—proved unreliable. A surprising number of apparently teratological forms occurred in various collections as follows:

*Hosaka* 540, Kipapa Gulch, Waipio, S ridge, 1000', May 1932: a complete androgynous spike arising from a perfectly formed utricel

*Krauss* 348: an extension of the axis within the perigynia reminiscent of the barb in *Uncinia*

*Rock* 8753, at the shore, Nahiku, Maui, May 10, 1911: a compounding of the spikes by numerous branchings from the base of each normal one to form a dense head

*Forbes* 1862.M: extremely large fruit as much as three times as large as normal

*Carex montis-eeka* Hillebrand, Flora of the Hawaiian Islands 486, 1888.

Figs. 4a-c, 5

*Carex montis-eeka* Hillebd. var. *viridens* Kükenth., Fedde Rep. 16: 435, 1920.

Rootstocks loosely caespitose; basal scales 7-8 mm. wide, 10 cm. long, 2-5 per culm, reddish, persistent; fertile culm, 2-3 mm. wide, 75 cm. long, with cross section triangular to semicircular, smooth, strongly veined, hollow, distinct from the leaves near the base, stiffly erect; leaves 1-2 mm. wide, 70 cm. long, 5-8 per culm, stiffly erect, clumped, strongly involute, glabrous, dark green; sheaths 15 cm. long, closed by a tight hyaline membrane; inflorescence 5-10 mm. wide, 2-7 cm. long, with 2-5 nodes, one spike to a node, lower internodes 1-3 cm. long, upper internodes shortened to 1-2 mm., or all spikes arising from a common terminal node; spikes androgynous except terminal spike which is staminate, 3-5 mm. wide, 1-3 cm. long, sessile or short pedunculate with an open ochrea at the base adjacent to the culm; pistillate bracts 1.5 mm. wide, 3 mm. long, ovate, chartaceous, 1-3-nerved, glabrous, green to brown; staminate bracts 4-5 mm. long, lanceolate, acuminate, 1-3-nerved; perigynia ovoid to lanceoloid, concave-convex to bi-convex, 1.5-2 mm.

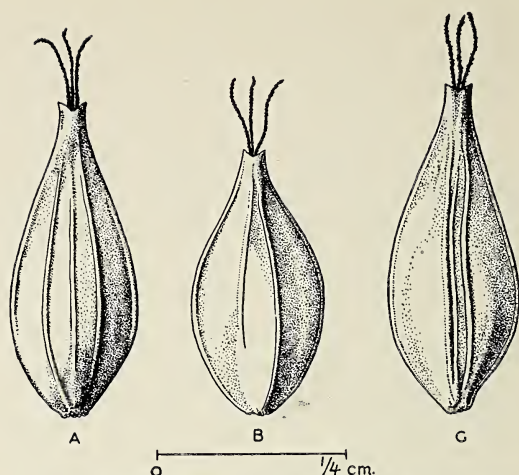


FIG. 4. Perigynia of *Carex montis-eeka* Hillebd. a, *Forbes* 418.K, b, *Fosberg* 10039; c, *Degener* 8264.

wide, 3-5 mm. long, toothed on the upper third of the margin, otherwise smooth, 1-3 nerved near the center on the convex side, singly nerved or not nerved on the concave side, rostrum tapering to a shallowly bidentate apex; achenes isosceles triangular in cross section, obovate, 2-2.5 mm. wide, 1.5 mm. long, truncate at the base, rugose, smooth and slightly ridged at the angles, light brown, rostrum 0.2 mm. long, bent back on the achene; style 1 mm. long dividing into three stigmas 2-3 mm. long, dark brown, glandular.

*Distribution:* on Kauai, Molokai, and Maui, in Zones D<sub>3</sub> and E<sub>1</sub> (Ripperton and Hosaka, 1942), the middle forest bog zone, in extremely wet, high bogs above 3,800 feet or in ponds in the bogs.

*Lectotype:* J. F. Rock 8190, summit of Puu Kukui, West Maui, Aug. 21, 1910.

No types or isotypes collected by William Hillebrand are available. The specimens were in the Berlin Herbarium, which was destroyed by fire in 1944. The entire collection of the Cyperaceae was lost. The collection of Rock cited above as the lectotype is from the same area as that cited by Hillebrand and contains many duplicates. It has been established that



the Hillebrand specimens cited as being from Mt. Eke are actually from Puu Kukui, the only area in which he collected in this high bog region.

### *Specimens examined*

**KAUAI:** *Cranwell, Selling, and Skottsberg* 2870, Alakai between Lehua makanoe and Kilohana, Aug. 15, 1938; *Degener* 2204, Waimeke, June 28, 1926, (NY); *Faurie* 1204, Hanapepe, Dec. 1909, (KY); *Forbes* 418.K, Kaholuamanu behind Waimea, Sept., 1908; *Forbes* 881.K, Alakai Swamp, Waimea drainage basin, west side, July 3–Aug. 18, 1917; *Forbes* 1155.K, Alakai Swamp, Waimea drainage basin, July 3–Aug. 18, 1917; *Hitchcock* 15488, Waialeale, 3600–5080', Oct. 22–24, 1916, (K); *Hitchcock* 15515, Kauluwehi Swamp, near Kaholuamanu Bog, Oct. 25, 1916, (K); *Rock* 9016, Kauluwehi Swamp, Waimea drainage basin, July 3–Aug. 18, 1917; *St. John* 10773, NW end of Alakai Swamp, Na Pali, 3800', Dec. 27, 1931; *St. John* 13569, Kahili Bog, 2100', Dec. 24, 1933; *Skottsberg* 943, Alakai Swamp near Kilohana, 1500 m., Oct. 27, 1922.

**MOLOKAI:** *Cranwell, Selling, Skottsberg* 2529, Pepeopae Bog, July 7, 1938; *Degener* 8235, Pepeopae Bog, May 3, 1928, (NY); *Degener* 8237, Pepeopae Bog, May 8, 1928, (NY); *Forbes* 199.Mo, mountains above Puu Kolekole, July 1912; *Hitchcock* 15192, central Molokai bog, 4000', Oct. 13, 1916; *Munro* 379, above Pelekunu, May 6, 1916; *Munro*, Kaunakakai, Jan. 1904; *St. John* 12560, Kawela ridge between Hanalilolilo and Pepeopae, 4100', Dec. 25, 1932.

**MAUI:** *Bryan* 641, Puu Kukui, 5200', Dec. 20, 1928; *Degener* 8258, Mt. Ekee, Aug. 29, 1927, (NY); *Degener* 8257, Mt. Ekee, Aug. 30, 1927, (NY); *Degener* 8264, Mt. Ekee, Aug. 27, 1927, (NY); *Ewart* 78, Puu Kukui, pond, 4800', Dec. 18, 1928; *Ewart* 45, Puu Kukui, 5700', Dec. 20, 1928; *Forbes* 465.M, Eke-Honokahau drainage basin, Sept. 25–Oct. 1917; *Forbes* 1182.M,

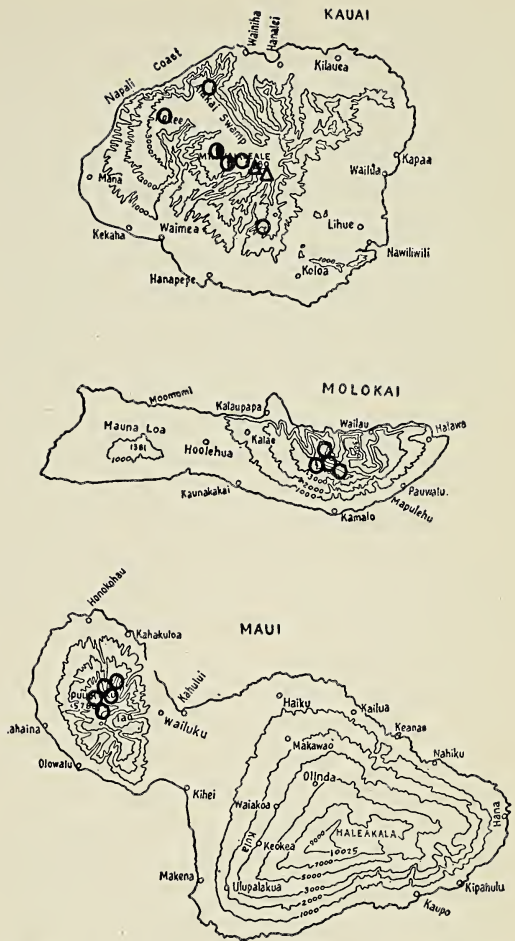


FIG. 5. Distribution of *Carex montis-eeka* Hilleb. (indicated by circles) and of *C. montis-eeka* forma filifolia (Skotts.) R. Krauss (indicated by triangles).

Waianapanapa Haleakala, Aug. 20, 1919; *Fosberg* 10039, Puu Kukui, pool, 1700 m., Aug. 24, 1933; *Hitchcock* 14840, Puu Kukui, 5000', Sept. 24–26, 1916; *Krauss* 424, Puu Kukui, 5500', Sept. 8, 1948; *Krauss* 468, Puu Kukui, 5300', Sept. 10, 1948; *Rock* 8190, Summit of Puu Kukui, Aug. 21, 1910; *St. John* 10262, Puu Kukui, 5750', Feb. 7, 1930; *Skottsberg* 741, top bog of Kukui, 1800 m., Sept. 10, 1922.

*Carex montis-eeka* Hilleb. is the only Hawaiian representative of section *Extensae* Fries (or *Spinostachyae* of Drejer) (Küken-

thal, 1909: 657). The section is widespread, occurring on all the continents, with a particular complex in Australia. As judged from written descriptions and plates *Carex montis-eeka* Hillebd. seems to approach *Carex serotina* Merat. (*Carex Oederi* Retz.) (Kükenthal, 1909: 301–303). It differs in the central nature of the perigynial veining, and in the extreme rigidity of the culm and involute leaves found in *Carex montis-eeka* Hillebd.

Skottsberg (1944: 333) uses the spelling *montis-Eke*, applying Article 70 of the International Rules of Nomenclature. The capitalization of Eke is permissible (Art. 70, note 1), but there is no indication that "eeka" is an unintentional typographic or orthographic error even if it may be a corruption of the present spelling for Mount Eke. The original spelling must be retained in the absence of such proof.

Kükenthal (1909: 435) describes *Carex montis-eeka* var. *viridens* as follows: "Squamae tenuiores pallidiores. Utriculi squamos large superantes oblique patentes virides nitidi oblongo elipsoidei, in rostrum magis conspicuum emarginatum abeuntes. Sandwich Inseln: Kauai, Hanapepe (Faurie no. 1204)." The type was secured and examined for these characters. The bracts are scarcely shorter than the large perigynia. They are slightly more hyaline than is usual but certainly not exceptional enough to indicate genetic difference. The rostra are only slightly more strongly bidentate than those in the rest of the population. Other Kauai specimens were examined to determine the constancy of the characters given. *Cranwell, Selling, and Skottsberg* 2807, collected in the region of the Faurie number, has the characters given by Kükenthal. The perigynia exceed the bracts by at least half their length; they are at an oblique angle with the rachis; they are green and shiny; and there is a slight groove in the rostrum. From the fresh stigmas it is clear that this is an immature specimen. The scales are still green and in growing condi-

tion, the lower older ones already much larger than the upper ones. The characters given are all those of a young inflorescence. None of the other Kauai specimens shows these features except in the more immature spikes.

*Carex montis-eeka* Hillebrand f. *filifolia* (Skottsberg) comb. nov.

Fig. 5

*Carex montis-Eke* var. *filifolia* Skottsberg, Acta Horti. Gotob. 15: 333, 1944.

Fruiting plants like those of the species but dwarfed; fertile culms 10–12 cm. tall, rarely to 33 cm. tall; leaves 0.1–0.5 mm. wide, 10–15, rarely 25, cm. tall, awl-shaped, channeled; inflorescence of 2–3 spikes, 3–6 perigynia per spike.

Type: L. M. Cranwell, O. Selling, C. Skottsberg 3042, summit of Waialeale, Kauai, Aug. 23, 1938.

#### *Species examined*

KAUAI: *Cranwell, Selling, Skottsberg* 3059, summit region of Waialeale, Aug. 23, 1938; *Cranwell, Selling, Skottsberg* 3042, (See Type); *Rock* 12754, Waialeale Swamp, Oct. 10, 1911.

*Carex montis-eeka* Hillebrand var. *filifolia* Skottsberg is retained as a form although only three specimens have been collected and one of these is less distinct than the others. Essentially, the difference is in the dwarf filiform aspect of the vegetative parts. Inspection of the plants, however, indicates that the rhizome is an old one and the growth habit is constant. The plant is found only on Mount Waialeale in Kauai well within the geographic and ecologic range of the species.

The variety is being reduced to a form not out of a desire arbitrarily to change categories but from the belief that this form is an unusual biotype of the species only ecologically modified to the stature at hand. Further collections of a large mass of material



of this form might indicate that it is a true variety with hereditary characters. On the other hand further collections of intermediates would validate the view now taken or cause complete union of this population with that of the species.

*Carex Svenonis* Skottsberg, Acta Horti. Gotob. 15:329–333, 1944.

Figs. 6a–c, 7

*Carex Svenonis* var. *alakaiensis* Skottsberg, Acta Horti. Gotob. 15:330–333, 1944.

Rootstocks caespitose, freely branching; basal scales 2–3 mm. wide, 0.5–2.5 mm. long, 1–3 per culm, fibrillose, caducous, brown, many fertile culms in a tuft (10–15 per 16 sq. cm.); fertile culm unequally triangular, slender, broadest side 0.5–0.9 mm. wide, 25–30 cm. long, faces slightly concave, glabrous, pendent to erect; leaves filiform to slender, pendent at the ends, three-sided, deeply grooved on one side near the base, slightly so at the tip, scabrous on the three sides, light green; sheaths broad, membranous, enclosing culm and younger leaves up to 8 cm. above the rootstock, tight, brown to green; inflorescence 5 mm. wide, 2–5 cm. long, 3–7 spikes per culm, one spike per node, the lower nodes 1 cm. apart, the upper closer, each spike subtended by a leafy bract

which narrows at once to a filiform, scabrous awn, 0.5–8 cm. long; terminal spikes staminate, lateral spikes androgynous, gynaeandrous, or both, 3–4 mm. wide, 3–12 mm. long, sessile, subtended within the leafy bract by a large bract or scale; pistillate bracts 1.5 mm. wide, 1.5–2.8 mm. long, broad ovate to triangular, hyaline with a single broad, dorsal nerve, acuminate, smooth on margins; staminate bracts similar, slightly reduced; perigynia 1–1.5 mm. wide, 1.5–3.5 mm. long, ovoid, convex-concave, strongly invaginate or cordate at the base, sessile or short stipitate, distinctly 5–9-nerved, glabrous, rostrum indistinct, scarcely separate from the gradually tapering body, broad, toothed, the apex unequally shallowly bidentate, frequently splitting down the entire length of the perigynia along a weakened line in the center of the convex side; achenes ovate, stipitate, glabrous, tan; style 0.5 mm. long, dividing into two stigmas 2–3 mm. long, tapering, glandular, reddish.

*Distribution:* Hawaii and Maui above 5,000 feet in Zones D<sub>3</sub> and E of Ripperton and Hosaka (1942), in bogs or wet regions of the upper forest.

*Type:* S. Berggren, Aug. 1875, Hawaii, in silva montis Mauna Kea.

*Specimens examined*

MAUI: *Forbes* 1181.M, Bog below Waianapanapa, Aug. 20, 1919.

HAWAII: *Degener* 19223, 29 miles, Kilauea, June 7, 1929, (NY); *Forbes* 934.H, In 1880–1 flow below Kipuka ahiu, June 24, 1915; *Skottsberg* 6781, Piihonua, on Puu Oo trail near crossroad, Apr. 7, 1948.

This species is a member of subgenus *Viginea* Beauv. (Kükenthal 1909:111), section *Elongatae* Kunth (Kükenthal 1909:226). This section presents a large number of species of worldwide distribution. The characters differentiating the species are so minor that the vast majority must be reduced to synonymy. Mackenzie lists a group of 19 species under section *Stellulatae* of Kunth.

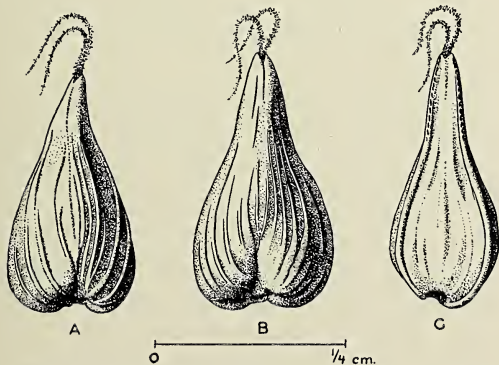


FIG. 6. Perigynia of *Carex Svenonis* Skottsberg. a, *Forbes* 934.H; b, *Forbes* 1181.M; c, *Forbes* 934.H (ventral side).

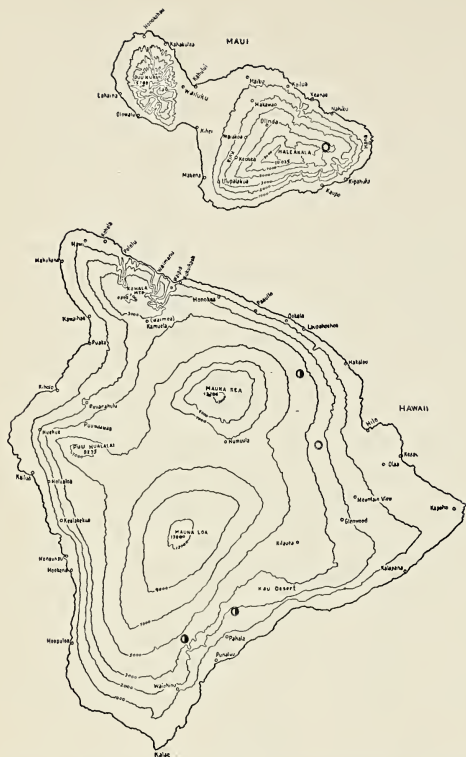


FIG. 7. Distribution of *Carex Svenonis* Skottsbg.

The characters used to differentiate these species—the shape of the teeth on the margins of the perigynia; intensity of nerving, width of leaf blades, etc.—are not reliable. Kükenthal has split the species *Carex stellulata* Good into 12 varieties and forms on characters little better than these but which conform to likely geographical distribution. It is felt that his more conservative treatment is more nearly the one to be accepted.

In his discussion of the new species *Svenonis*, Skottsberg (1944:330) writes at length concerning its status. He points out clearly the difficulties involved in placing the new plant in the midst of a confusion of closely related species which have not been critically monographed. His conclusion is, "It is possible that *Carex Svenonis* does not deserve the rank of a species, certainly not if *Carex echinata* (*stellulata*) is taken in the wider sense of Kükenthal. In any case it is

an addition to the Hawaiian flora." Skottsberg does not give enough evidence to delineate a new species from others in section *Stellulatae*. The only character that is of value is the occurrence on some culms of staminate terminal spikes, but this character is found in certain of the North American species (*Carex bromoides* Schkuhr.) and, according to Kükenthal, it also occurs in the species *stellulata* as well as in the section *Elongatae*. However, the species that are published must be critically revised for the world. No helpful decision can be reached for one species without a study of the entire sections *Stellulatae* Mack. and *Elongatae* Kunth. It seems unwise at this time to state that *Carex Svenonis* cannot be distinguished from any of many closely related species, when it is not even possible to determine those species from which it cannot be distinguished. *Carex Svenonis* and a large number of untenable segregates must be retained until that revision is made.

*Carex Meyenii* Nees, Nova Acta Acad. Leop., Carol. Nat. Cur. 19, Suppl. I, 1843.

Figs. 8a-c, 9

*Carex Remyi* Boeckeler, Flora 58: 269, 1875.

*Carex brunnea* Thunb. var.  $\beta$  Hillebd., Flora of the Hawaiian Islands 489, 1888.

*Carex brunnea* var. *Meyenii* Kükenth. Engler's Pflanzenreich IV, 20:601, 1901.

Rootstocks caespitose forming clumps to 40 cm. in diameter; basal scales 3–5 mm. wide, 0.5–1.5 mm. long, 5–10 per culm, ovate, multinerved, rich brown; fertile culm, 1–1.5 mm. wide, 30–60 cm. long, sharply triangular, smooth below, lightly scabrous above, pendent to semi-erect; leaves 2–3 mm. wide, 30–60 cm. long, 5–15 per culm, dark green; pendent narrow, lightly scabrous on main veins and margins, sheaths tight, closed by a hyaline, deeply notched membrane ex-



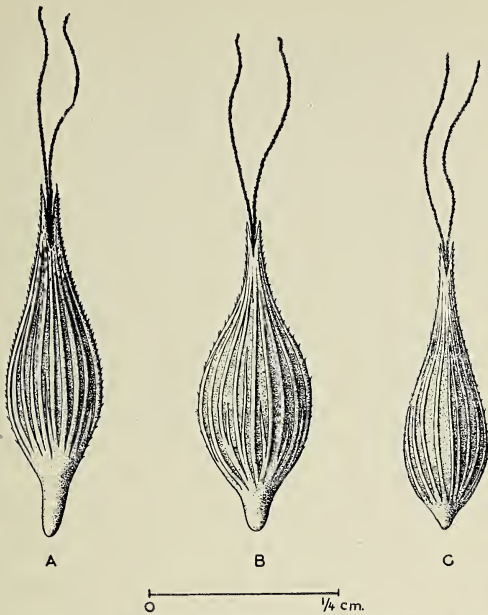


FIG. 8. Perigynia of *Carex Meyenii* Nees. a, *St. John & Catto* 17613; b, *St. John* 10382; c, *Rock* 8752.

tending 5–10 cm. above the rootstock, dark brown at the base; inflorescence 5–25 cm. long, pendent, 4–6 spikes arising from a node, 4–10 nodes per culm, each node subtended by a leafy bract 8–15 cm. long, lower internodes 2–4 cm. apart, upper internodes shortened, upper leafy bracts reduced to scales; spikes 2–3 mm. wide, 2–4 cm. long, androgynous, peduncles 1.5–3 cm. long, with membranous tubular cladophylla or ochreas 2–3 cm. long; pistillate bracts 1 mm. wide, 3 mm. long, hyaline, keeled, obscurely nerved; staminate bracts 0.8 mm. wide, 4 mm. long, lanceolate, keeled, hyaline-margined; perigynia 1–1.5 mm. wide, 3–4.5 mm. long, with body from ovoid to lanceoloid, bi-convex to plano-convex, the base stipitate, greenish-brown to brown, chartaceous-membranous, strongly 9–12-nerved on a side, rostrum one fourth as long as the body, often minutely toothed on the upper third, bidentate, teeth 0.5–0.8 mm. long; achenes lenticular, minutely rugose in longitudinal lines, light brown to greenish; style and stigma

3 mm. long, stigmas two, 2 mm. long, minutely glandular, dark brown.

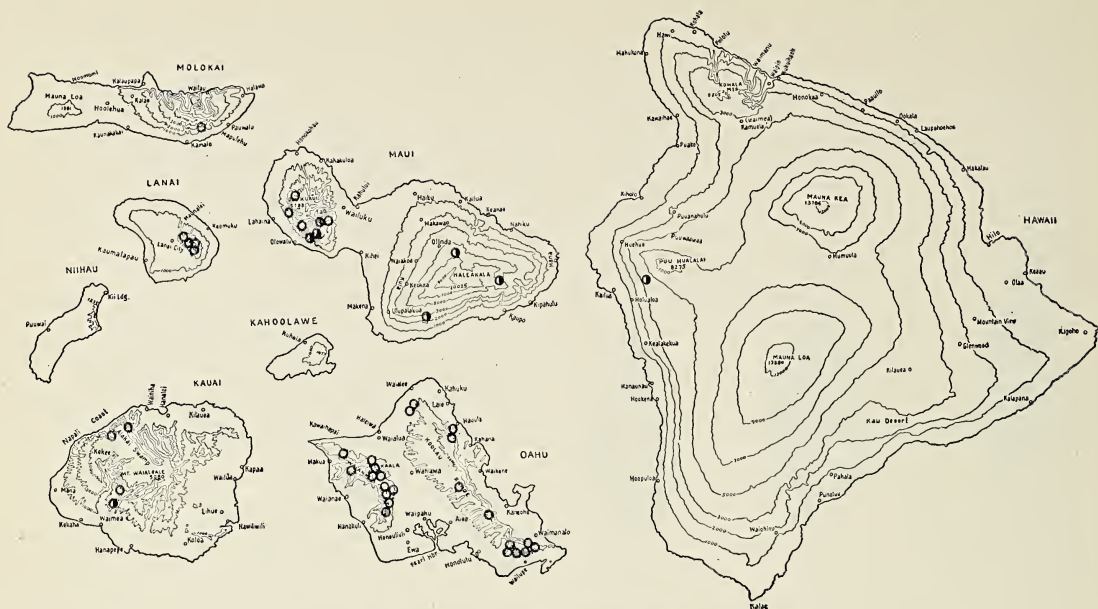
*Distribution:* On all islands in Zone D of Ripperton and Hosaka (1942), or middle forest between 600 feet and 3,500 feet on ridges in full sun or in dense shade and on moist rocky ravine walls. Optimum development in semi-shade.

*Type:* F. J. F. Meyen, in Oahu Insula Sandvicensium, June, 1831. The specimen is with the Meyen plants in the herbarium at Leningrad. Requests for the loan of plants from Leningrad were unanswered.

#### *Specimens examined*

KAUAI: *Faurie* 1201, Waimea, 1000 m., Mar. 1910, (KY); *Fosberg* 12673, head of Kalalau Valley, 1250 m., Dec. 29, 1935; *Mann & Brigham* 391, Waimea, 2000–3000', (C); *Nuttall*, Kauai (no data), (K); *Nuttall*, Kauai (no data), 1843, (K); *St. John* 22902, Kilauea Lookout, Kalalau Valley, 4000', Dec. 21, 1947.

OAHU: *Degener* 19412, N slope of Mt. Kaala, Feb. 2, 1949, (NY); *Faurie* 1209, Honolulu, Apr. 1909, (GB); *Faurie* 1211, Kaala, Nov. 1909, (KY); *Forbes* 2465.O, ridge between Niu and Wailupe, Apr. 11, 1917; *Forbes* 2525.O, Wailupe, Jan. 1919; *Fosberg* 10893, head of Makaha Valley, S side, 1500', Mar. 31, 1935, (US); *Fosberg* 13040, head of Kapuna Valley, Mokuleia, 600 m., Apr. 11, 1936; *Fosberg* 13602, head of Kawaihapai Gulch, Feb. 21, 1937; *Fosberg* 13005, E ridge of Puu Kalena, 950 m., Mar. 22, 1936; *Fosberg* 13631, N ridge of Puu Kumakalii, Mar. 28, 1937; *Gaudichaud*, near Honolulu and the Pali, 1836, (K); *Judd & Hosaka*, Pahaia Valley, sixth valley E of Makaliha, 1200', Dec. 2, 1931; *Krauss* 122, trail to Puu Kaua, 1800', Feb. 29, 1948; *Krauss* 119, trail to Puu Kaua, 1700', Feb. 29, 1948; *Krauss* 137, Papoli ridge above Maakua, 600', Mar. 21, 1948; *Krauss* 141, Papoli ridge above Maakua, 450', Mar. 21, 1948; *Krauss* 148, third ridge N of Palikea,

FIG. 9. Distribution of *Carex Meyenii* Nees.

W side, 2000', Mar. 26, 1948; *Krauss* 300, summit of Kuliouou Trail, Aug. 6, 1948; *Krauss* 299, below summit of Kuliouou Trail, Aug. 6, 1948; *Krauss* 298, below summit of Kuliouou Trail, Aug. 6, 1948; *Krauss* 291, Kuliouou Trail, 1200', Aug. 6, 1948; *Krauss* 290, Kuliouou Trail, 1200', Aug. 6, 1948; *Krauss* 317, Palolo Trail to Kaau Crater, 1400', Aug. 13, 1948; *Krauss* 557, Stream bed of Elehaha, 500' from Road, 850', Apr. 16, 1948; *Mann & Brigham* 260, Waialua Mts., (C); *Remy* 141, 1851-55, (GH, P); *St. John* 11026, Kipapa Gulch, second N fork, Waipio, 1300', Feb. 15, 1937; *St. John* 10382, N fork of valley E of Palikea, 1300', Feb. 23, 1930; *St. John* 13156, Pohakea Pass, 2200', May 12, 1933; *St. John* 14037, E ridge of Puu Kanehoa, 2400', Jan. 7, 1934; *Skottsberg* 44, Keawaawa, Aug. 4, 1922; *Wilkes Exped.*, Honolulu, 1838-42, (US).

MOLOKAI: *Faurie* 1207, Kamalo, June 1910, (KY); *Forbes* 361, Kaluaaha Valley, Aug. 1912.

LANAI: *Fagerlind & Skottsberg* 6767, summit of main ridge in wet forest, Apr. 2, 1948, (GB); *Fagerlind & Skottsberg* 6419,

NW part of main ridge, Feb. 25, 1948, (GB); *Fosberg* 12480, ridge below Puu Aalii between Maunalei drainage and Hauola drainage 2600', Nov. 30, 1935, (US); *Hitchcock* 14666, on largest mountain, Sept. 21, 1916, (US); *Munro* 155, ridge above Hookio, Oct. 11, 1913; *Munro* 451, Hookio, Oct. 6, 1913; *Rock* 8083, Mahana, July 25, 1910; *St. John* 18705, Puu Ealii, Kealia Aupu-Kaunolu, 2700', Apr. 9, 1938.

MAUI: *Forbes* 320.M, Lahainaluna Valley, Feb. 19, 1913; *Forbes* 2391.M, Olowalu Valley, May 17, 1920; *Forbes* 2047.M, Kalualii, middle Auwahi, Mar. 20, 1920; *Forbes* 2406.M, Olowalu Valley, May 17, 1920; *Forbes* 699.M, NE of Ukulele, July 9, 1919; *Hitchcock* 14961, Haleakala crater, 6000-10,000', Oct. 2-5, 1916, (US); *Hitchcock* 12900, Haleakala, 6000-10,000', Oct. 2-5, 1916; *Krauss* 464, confluence of Honokawai and Waikiki, Sept. 11, 1948; *Rock* 8752, Waikahu Valley, 900', May 1911; *St. John & Catto* 17613, S ridge of Launiupako Valley, 2550', Dec. 20, 1936.

HAWAII: *Skottsberg* 631, slope of Hualalai, 1200 m., Sept. 23, 1922.



*Carex Meyenii* Nees belongs to the subgenus *Eucarex*, Coss. & Germ., section *Hymenochlaenae*, Drejer (Kükenthal 1909: 576), subsection *Graciles*, Tuckerman (Kükenthal 1909: 599). The subsection is widespread in the Pacific from South America to the center of Asia. The Hawaiian plant has been described as *Carex Remyi* by Boeckeler, as *Carex Meyenii* by Nees, and, in part, as *Carex Commersoniana* by Kunth, all believing it to be a distinct species. *Carex Commersoniana* Kunth is described with "Sieb herb. Maurit. no. 50" cited as the type immediately following the binomial. However, after the description, *Carex Meyenii* of Nees is cited as a juvenile specimen of *Carex Commersoniana*. Kunth's description does not fit the Hawaiian plant, nor does Plate 155 of F. Boott in *Illustrations of the Genus Carex*, which was drawn from Mauritian material. There is no question that Kunth is naming the plant now known as *Carex brunnea* Thunb. under which Kükenthal cites Sieber herb. Maurit. no. 50. *Carex Commersoniana* Kunth is a later homonym of *Carex brunnea* Thunb. and cannot be applied to the Hawaiian species. Hillebrand (1888: 489) describes it as a new variety,  $\beta$ , of *Carex brunnea* based on Mann & Brigham 391. Kükenthal also describes it as a variety of *Carex brunnea*.

Authentic specimens of the Japanese *Carex brunnea* Thunb. were secured from the University of Kyoto, Japan. They are not the same species as the Hawaiian plant though they do clearly belong to the same subsection. The differences are pronounced. The perigynia in the Hawaiian plants are lanceolate with long tapering rostra. Those in the Japanese material (Faurie 4945) are broadly ovate to circular in outline with an abrupt narrow rostrum. Further, the surface of the perigynia in the Japanese material is strongly hispid with prominent white hairs. The Hawaiian perigynia have only setae on the margins. The bracts in the Japanese specimens

are broad ovate; those in the Hawaiian ones are much narrower.

The perigynia, in fact, more closely approach those in the Chinese *Carex longicruris* Nees. However, the long stigmas and the extreme branching spikes as well as the greater size in the latter make it a remote member of the subsection.

*Carex Meyenii* Nees is found on all the main islands but seems to have its center of distribution in the west, indicating a center of dispersion from either Kauai or Oahu.

*Carex Nealae* sp. nov.

Figs. 10a-c, 11

Rhizomatis distinctis lignosis caespitosis in apicibus, squamis radicibus 4-6 mm. latis 1-4 cm. longis 2-5 in culmis caducis, culmis 1.5-2 mm. latis 30-45 cm. longis erectis triangulis striatis glabris fuscis, laminis 4-5 mm. latis 15-50 cm. longis 3-10 in culmis saepe ad apicem compressis inflorescentiis excedendis marginibus superioribus scabris inferioribus glabris, vaginis membranis hyalinis clausis laminis culmibusque in fasciculo tenendis, inflorescentiis 3-4 mm. latis 4-6 cm. longis ramosis nodis 1-5 spiciferis 1-5 nodis, internodiis inferis 1-2 cm. longis supris brevioribus, nodis bractis laminiferis inclusis, spicis 3-4 mm. latis 1.5-5 cm. longis androgynis praeter terminalis masculis multifloribus, pedunculis 3-5 mm. longis includendis in ocreis bipartitis in apicibus purpureimaculosis, squamis foeminis 1.4 mm. latis 2.5 mm. longis ovatis emarginatis cum costa alba interdum breve aristatis brevibus marginibus hyalinis rubris aut purpureis, squamis masculis 1.5 mm. latis 5 mm. longis lanceolatis emarginatis costa alba in marginibus rubris aut purpureis, utriculis 1.5-2 mm. latis 3-4 mm. longis ovoideis aut latis ovoideis stipitatis valde 5-6 nervosis fuscis cum glandibus rubris maculosis, rostris brevibus apicibus integribus, achenis obovoide biconvexis rugosis fuscis, stylis in duo stigmatibus glandulosis 2-3 mm. longis divisis.

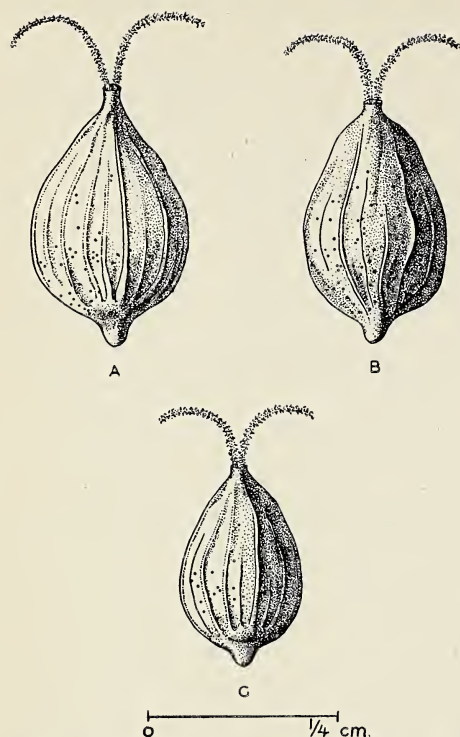


FIG. 10. Perigynia of *Carex Nealae* R. Krauss. a, Forbes 1187.M; b, Forbes 1191.M; c, Neal and Hartt 698.

Rhizome distinct, branching, lignescent, becoming caespitose at the apex; basal scales 4–6 mm. wide, 1–4 cm. long, brown, fibrillose, 2–5 per culm, caducous; fertile culm, 1.5–2 mm. wide, 30–45 cm. long, triangular in cross section, erect, stiff, striate, smooth on the angles, brown; leaves 4–5 mm. wide, 15–50 cm. long, slender, erect, 3–10 per culm, V-shaped, often folded to the apex, long, tapering, usually exceeding the inflorescence, sparsely scabrous on the upper margins, smooth below; sheaths closed by a hyaline membrane splitting almost at inception, holding culms and leaves in slender bundles 9–15 cm. above the base, dark brown; inflorescence 3–4 mm. wide, 4–6 cm. long, apical, erect, branching, one spike per node, 1–5 nodes per inflorescence, lower internodes 1–2 cm. long, the upper shorter, each node enclosed by a leafy bract, the lower 10–15 cm.

long, the upper shorter; spikes 3–4 mm. wide, 1.5–5 cm. long, androgynous except the terminal spike which is staminate, densely flowered, peduncles 3–5 mm. long, enclosed by a split ochrea 1–2 mm. long, purple-spotted at the apex; pistillate bracts 1.5 mm. wide, 2.5 mm. long, ovate, predominantly strongly emarginate with a single white dorsal nerve sometimes extending into a short awn, margins hyaline, red to purple; staminate bracts 1.5 mm. wide, 5 mm. long, lanceolate, emarginate, white along dorsal nerve, red to purple in margins; perigynia 1.5–2 mm. wide, 3–4 mm. long, ovoid or broadly so, bi-convex, short stipitate, strongly 5–6-nerved, brown, chartaceous, numerous spotted with reddish glands; rostrum tapering to an entire apex, achenes obovoid, bi-convex, more convex on one side than the other, minutely rugose, dark brown; style splitting into two spreading stigmas at the apex of the rostrum, stigmas 2–3 mm. long, glandular.

*Distribution:* Hawaii and Maui in Zones D and E of Ripperton and Hosaka (1942), the middle and upper forest, growing in bogs and pools in pahoehoe lava in full sun, rare.

*Type:* Forbes 1191.M, Waianapanapa, at edge of lake, Haleakala, Maui, Aug. 20, 1919.

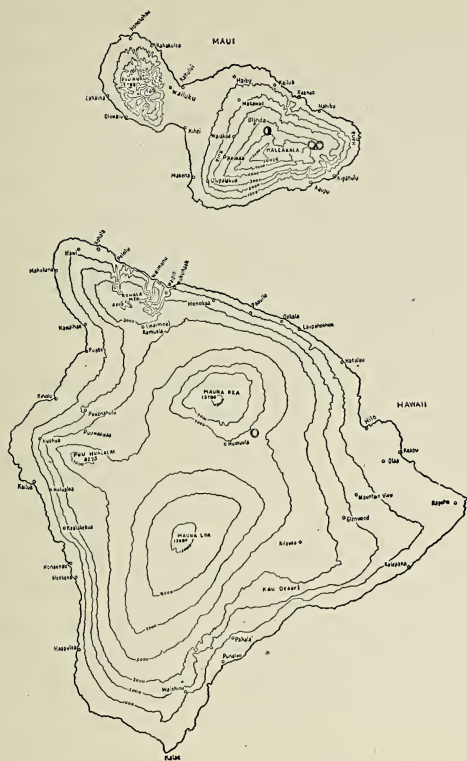
#### *Specimens examined*

MAUI: Forbes 861.M, East of Ukulele, July 20, 1919; Forbes 1187.M, Waianapanapa, Haleakala, Aug. 20, 1919; Forbes 1191.M (See Type).

HAWAII: Neal M., and Hartt, C., 698, East of Humuula below Kalaechea in pool, 6200', Aug. 7, 1935.

*Carex Nealae* belongs in subgenus *Eucarex* Coss. & Germ., section *Acutae* Fries subsection *Vulgares* Aschens (Kükenthal 1909: 305). It has unquestioned Australian relationships, being close to *Carex Gaudichaudiana* Kunth, which grows in bogs in the mountains of New South Wales and New Zealand. It differs from this species, how-



FIG. 11. Distribution of *Carex Nealae* R. Krauss.

ever, in several respects. In *Carex Nealae* the pistillate bracts are predominantly strongly emarginate and the margins are reddish-purple and opaque. In *Carex Gaudichaudiana* Kunth the pistillate bracts are all obtuse, and are light brown with hyaline margins. The spikes in *Carex Nealae* are 4–5 cm. long; those of *Carex Gaudichaudiana* Kunth are semi-globose, reaching only 2 cm. in length. The margins of the narrower leaves of *Carex Gaudichaudiana* Kunth are involute; those of *Carex Nealae* are not.

The species is named out of respect for Miss Marie Neal of the Bernice P. Bishop Museum Herbarium, who collected the plant on Hawaii in 1930.

The distribution of *Carex Nealae*, at present collected only four times, suggests that it is to be found at the edges of stagnant water at elevations over 3,000 feet. How-

ever, the vegetation need not be primarily bog type.

*Carex macloviana* D'Urv. (1826: 599) var. *subfusca* (W. Boott) Kükenth. Engler's Pflanzenreich, IV: 20, 197, Pl. V, 1909.

Figs. 12a–c, 13

*Carex subfusca* W. Boott. In: Botany of California 2:234, 1880.

Rootstocks caespitose, forming small clumps 15–20 cm. in diameter; basal scales two to four, 2–3 mm. wide, 1–5 cm. long, persistent, brown; fertile culm triangular in cross section, sides 0.6–1 mm. wide, 15–60 cm. long, strongly ribbed, scabrous on the angles, pendent, leaves 1–2 mm. wide, 10–70 cm. long, narrow, scabrous along midrib and margins, pendent, dark green; sheaths tightly closed by a chartaceous to hyaline membrane which splits almost at once to 10 cm. above the rootstock, brown; inflorescence forming ovoid to cylindric head, 0.8–1 cm. wide, 1–2 cm. long, densely flowered, 4–9 spikes closely spirally arranged at the apex of the culm, internodes 1–2 mm. apart, each spike subtended by a bract, the lower leaf-like to 1 cm. long, the upper scale-like; spike gynaecandrous, 2–3 mm. wide, 5–6 mm. long, sessile, subtended by a leafy bract or scale which may have stipule-like appendages; pistillate bracts, 1.5–2 mm. wide, 3 mm. long, obovate acute to acuminate, with minute teeth on the keel near the apex, membranous, brown with a green keel; staminate bracts similar; perigynia 1.5–2 mm. wide, 3–4.5 mm. long, narrowly lanceoloid, long, tapering to the apex, narrowly winged, strongly concave-convex, faintly several-nerved on each side or not nerved, chartaceous, brown to green, wing toothed on the margins, rostrum grooved on the convex side, deeply bidentate on the convex side, shallowly bidentate on the concave side; achenes ovoid, bi-convex, stipitate, surface shining golden, minutely punctate; style 1.5–2 mm. long, splitting at half its length into two glandular stigmas.

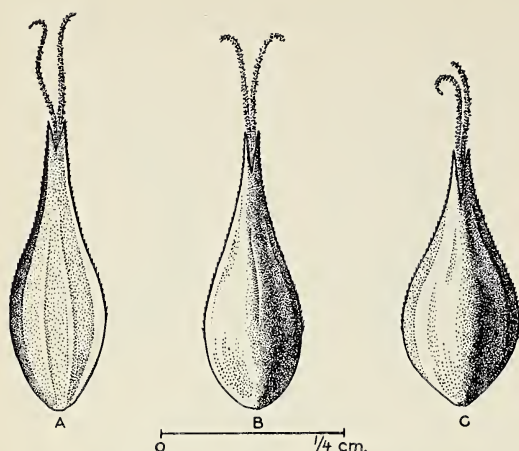


FIG. 12. Perigynia of *Carex macloviana* var. *subfusca* (W. Boott) Kükenth. *a*, *b*, Forbes 719.M; *c*, Giffard in 1911.

*Distribution:* Hawaii and Maui, in Zones D and E of Ripperton and Hosaka (1942), the upper forest, in dry, sunny meadows or grassy ravines, usually over 5,000 feet.

*Type:* Kellogg, Lake Tahoe, Bear Camp, Cal. (GH); from Herbarium of William Boott.

#### *Specimens examined*

MAUI: Cranwell, Selling, Skottsberg 2794, Haleakala, 2200 m., Aug. 4, 1938, (GB); Degener, Koolau Gap, June 29, 1929, (NY); Degener 9014, Mauka of Ulupalakua, July 4, 1927, (NY); Degener 9013, Slope of Haleakala, Aug. 10, 1927, (NY); Degener 9011, Pipe Line, Olinda, June 14, 1927, (NY); Degener 9015, Koolau Gap, Haleakala, Aug. 19, 1927, (NY); Degener 9012, Koolau Gap, Haleakala, June 29, 1927, (NY); Faurie, Haleakala Crater, Aug. 11, 1909; Forbes 1248.M, Kaupo Gap, Haleakala, Aug. 25, 1919; Forbes 719.M, E of Ukulele, July 11, 1919; Forbes 975a.M, Pasture above Ukulele, July 29, 1919; Forbes 1010.M, Kaeanae Gap, Haleakala, Aug. 2, 1919; Forbes 1099.M, Haleakala, Kaupo Gap, Aug. 9, 1919; Forbes 1186.M, N slope of Haleakala, Waianapanapa, Aug. 20, 1919; Forbes 1227.M, Bog below Waianapanapa, Aug.

25, 1919; Hitchcock 14977, Haleakala, 6–10,000', Oct. 2, 1916; Krauss 350, Switchback Trail above Holua, 8000', Sept. 3, 1948; Krauss 355, Draw behind Paliku, 6800', Sept. 2, 1948; Krauss 343, half mile N of Paliku, 7000', Sept. 3, 1948; Krauss 341, half mile N of Paliku, 7000', Sept. 3, 1948; St. John 17776, Haleakala Crater, Cinder Flat, 7000', Dec. 26, 1936; Skottsberg 830, Haleakala, inside crater, W side, 2200 m., Oct. 16, 1922.

HAWAII: Degener 9009, Kipuka Puau, Kilauea, May 1932, (NY); Degener 9010, Kau Desert, 10 M. from Volcano House, June 16, 1929, (NY); Faurie 1219, Mauna Kea, 2000 m., July 1909; Faurie 1220, Mauna Kea, 2000 m., July 1909; Faurie 1218, In Kilauea Volcano, May 1909; Forbes, Kona, Hanehane, June 15, 1911; Forbes 177.H, Hualalai above Hanehane, June 16, 1911; Forbes 306.H, Mauna Loa

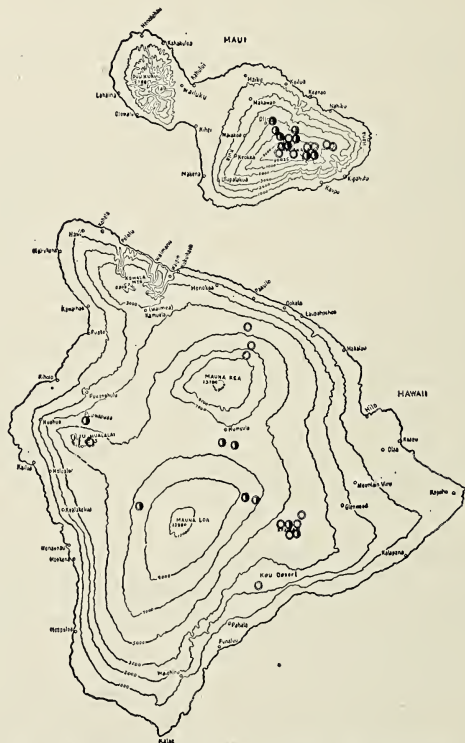


FIG. 13. Distribution of *Carex macloviana* var. *subfusca* (W. Boott) Kükenth.



below Pui-o-Uo, July 11, 1911; *Forbes* 972.H, Flow of 1823, Level of Keawewai, June 28, 1915; *Giffard*, Kilauea Volcano, June 1911; *Hapeman*, Volcano House, Kilauea, Apr. 23, 1908, (NY); *Hitchcock* 14528, Hualalai Mt., Sept. 2, 1916, (US); *Hitchcock* 14238, Kukaiau Ranch, 8000', Aug. 21, 1916, (US); *Hitchcock* 14226, Kukaiau Ranch, 3600', Aug. 20, 1916, (US); *Hitchcock* 14317, Maunakea, NE slope, 7000', Aug. 23, 1916, (US); *Mann & Brigham* 332, high central plateau of Hawaii; *Remy* 146, 1851-55, (GH); *Rock* 12731, Kilauea Volcano, July 1911; *St. John* 11438, Puu Hualalai, Kaupulehu, summit of volcanic cone, 8000', Dec. 30, 1931; *Skottsberg* 524b, E slope of Mauna Loa, Sept. 15, 1922, (GB); *Skottsberg* 570, Kilauea, Tree Fern Forest, Sept. 17, 1922, (GB); *Skottsberg* 494, Kilauea, crater trail, Sept. 12, 1922, (GB); *Skottsberg* 524, Trail to rest house, Mauna Loa, Sept. 15, 1922, (GB); *Wilkes Exped.*, 1838-42, (US).

*Carex macloviana*, in the subgenus *Vignea* (P. Beauv.) Nees (Kükenthal 1909: 111) section *Ovales* Kunth (Kükenthal 1909: 191), is a widespread and confusing species. Kükenthal has described 10 varieties and forms corresponding more to geographical regions than to characters. Specimens of a number of these varieties have been examined. They represent collections from California, Colorado, and Nevada in the United States, and from the Falkland Islands, Mexico, Greenland, Kamchatka, Canada, Unalaska, Sweden, and Chile.

The Hawaiian species show a clear relationship to the varieties *subfusca* (W. Boott) Kükenth. and *pachystachya* (Cham.) L. H. Bailey. They do not seem to be close to the varieties from South America which have perigynia which are more broadly winged, more strongly nerved, and less concave-convex in cross section. The latter include the type for *macloviana* sent from Santiago, Chile.

In my opinion many of the varieties of *Carex macloviana* D'Urv. represent differing biotypes with neither ecological nor genetic basis for their segregation. In specimens of the Hawaiian plant a clear gradation may be observed, often in the same inflorescence, from perigynia strongly nerved to not nerved, from strongly squarrose to not squarrose, etc.

The type collection of Kellogg from California has been examined. It corresponds very closely to the Hawaiian plant. It is not possible, without more material, to determine if *Carex subfusca* W. Boott is a good species. The world distribution of *Carex macloviana* D'Urv., and the slight differences in its population, prevent the retention of *Carex subfusca* W. Boott as a Linnaean species; however, its varietal status appears to be sound.

#### *Carex pluvia* sp. nov.

Figs. 14a-c, 15

*Carex sandwicensis* Boeckler (1875: 265)  
var. *laxiflora* Kükenth. Fedde Rep. XVI,  
435, 1920.

Rhizomatis caespitosis in glaebris laxis 30 cm. in diametrio, squamis radicum 7-8 mm. latis 1-5 cm. longis fibrillosis, culmis fertilibus 2-3 mm. latis 45-75 cm. longis erectis triangularibus concavis striatis glabris apicibus caulorum pendulis, 6-10 laminis 5-7 mm. latis 15-75 cm. longis pendulis culmis fertilis raro excedendis in marginibus saepe revolutis scabris in apice glabris in basi vaginis laxis membranace evanescentibus clausis, inflorescentis ramosis pendulis aut erectis 8-10 nodis unispiciferis pedunculis et ocreis in laminis-bracteis inclusis inflorescentiis excedendis, spicis 3-5 mm. latis 3-9 cm. longis multifructibus androgynis praeter spicis terminalis masculis, pedunculis in ocreis inclusis et squamis sterilis ocreis superioribus, squamis foeminis 1 mm. latis 4 mm. longis lanceolatis in centris triplinervosis ovatis acuminatis marginibus hyalinis fulvis, squamis

masculis 0.5 mm. latis 4–5 mm. longis 2–3 nervosis, utriculis 1–1.5 mm. latis 2–4 mm. longis ellipsoideis aut ovoideis aut ovatis-ellipsoideis, chartaceis fulvis enervosis aut trinervosis, breve stipitatis rostris bidentatis marginibus incrassatis raro setaciferis, achenis lenticularibus rugosis fulvis utriculis non complentibus, stylo 0.5–1 mm. longo erecti.

Rootstocks caespitose, forming loose clumps 30 cm. in diameter; basal scales 7–8 mm. wide, 1–5 cm. long, fibrillose; fertile culm 2–3 mm. wide, 45–75 cm. long, triangular in cross section, faces concave, erect, stiff, nodding only at the ends, striate, smooth; leaves 5–7 mm. wide, 15–75 cm. long, 6–10 per culm, pendent, slender, seldom exceeding the fertile culms, V-shaped in cross section, revolute at the margins, tapering, scabrous at the ends, smooth toward the base, light green; sheaths 3–8 cm. long, closed by a very thin rapidly disappearing membrane, loose, light brown; inflorescence pendent to semi-erect, branching, 8–10 nodes, one spike to a node, each node and ochrea bearing peduncle enclosed in a leafy bract exceeding the inflorescence by 1–10 cm.; spikes 3–5 mm. wide, 3–9 cm. long, androgynous except the terminal spike which is staminate, closely set with fruit, pedunculate, peduncles enclosed by an ochrea, several sterile scales above the ochrea; pistillate bracts 1 mm. wide, 4 mm. long, lanceolate to ovate, acuminate, triple-nerved in the center, green to yellow, margins hyaline, brown to red; staminate bracts lanceolate, 0.5 mm. wide, 4–5 mm. long, 2–3-nerved at the center; perigynia 1–1.5 mm. wide, 2–4 mm. long, ellipsoid, varying to ovoid or even obovoid-subspherical, chartaceous, yellow to brown, short stipitate, not nerved or with as many as three nerves, rostrum bidentate, margins ridged, occasionally armed with large, caducous setae; achenes lenticular, rugose, not filling the perigynia, yellow to brown; style erect, 0.5–1 mm. long, splitting into two glandular stigmas at the apex of the rostrum.

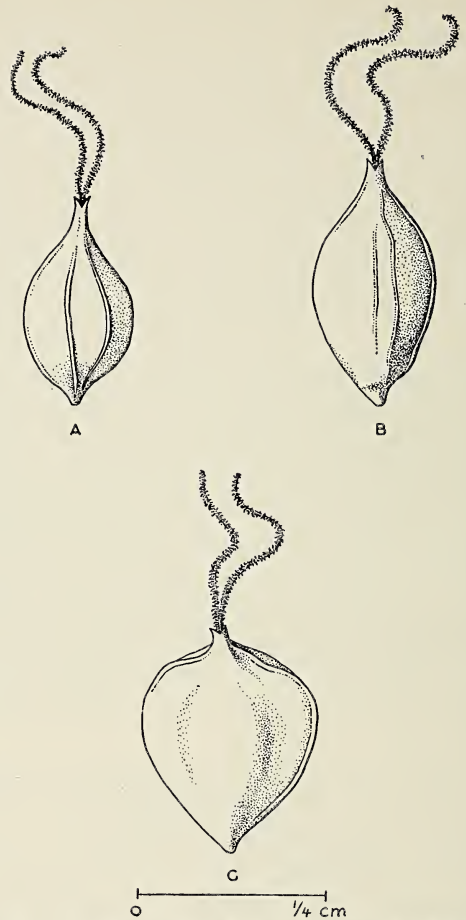


FIG. 14. Perigynia of *Carex pluvia* R. Krauss. a, Krauss 218; b, Fosberg 13757; c, Krauss 415.

*Distribution:* On all the islands, except Lanai, in Zone D<sub>2</sub> of Ripperton and Hosaka (1942), the middle forest, in very wet, shady places; often in the beds of streams or in the water.

*Type:* Krauss 218, In Kaluanui Stream among rocks beside rapidly flowing water, 1,950 feet, May 23, 1948.

#### *Specimens examined*

KAUAI: *Faurie* 1202, Waimea, 1000 m., Feb. 1910 (immature?); *Hitchcock* 15328, Kaholuamano, Mar. 3, 1901, (US); *Rock* 1665, Kaholuamano, Mar. 3, 1909; *Rock* 5042, Kaholuamano, Sept. 1909; *Smith*, *Whitney*, *Neal*, Kokee, 3500', May 1, 1929;



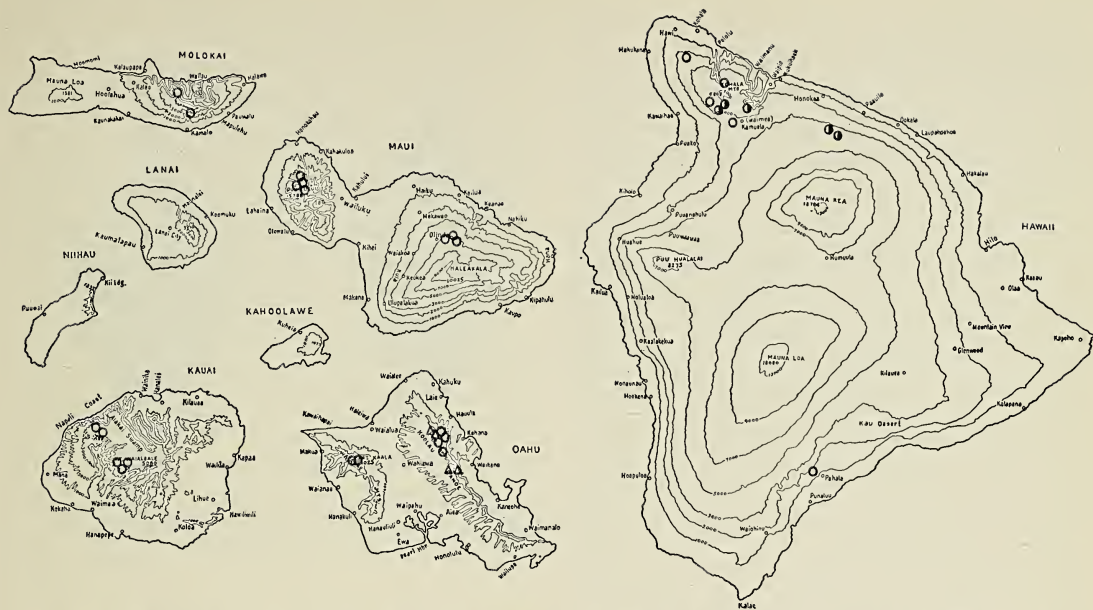


FIG. 15. Distribution of *Carex pluvia* R. Krauss (indicated by circles) and of *C. pluvia* var. *koolauensis* R. Krauss (indicated by triangles).

Wilder 450, Kokee Stream, 3600', Mar. 8, 1926.

OAHU: *Christophersen* 1747, top of Kaala, 1200 m., May 10, 1931; *Forbes & Clark*, between Punaluu and Kaipapau, May 3, 1909; *Fosberg* 13680, Puu Kaala summit, W side, Mar. 24, 1937; *Fosberg* 13757, Kaluanui Valley, 600 m., Apr. 25, 1937; *Krauss* 224, In Kaluanui Stream, 1950', May 23, 1948; *Krauss* 208, In Kaluanui Stream, 1950', May 23, 1948; *Krauss* 209, 210, 211, 212, 213, 214, 215, 216, 217, and 218 same data as 208; *Krauss* 505, in bed of Kaluanui stream, 1950', Nov. 21, 1948; *St. John & Cottam* 23556, Poamoho Stream, 2000', Feb. 20, 1949.

MOLOKAI: *Degener* 8236, S of Ohialele, May 8, 1928, (NY); *Hitchcock* 15094, North of Kamalo, 4000', Oct. 10, 1916, (US).

MAUI: *Degener* 8251a, Stream bed, Olinda Pipe Line, June 16, 1927, (NY); *Degener* 8248, Oohuola stream-bed near ditch trail, July 7, 1927, (NY); *Forbes* 1257.M, Kula Pipe Line, Waikamoi, Sept. 5–6, 1919;

*Forbes* 2602.M, Waikamoi Trail, June 25, 1920; *Forbes* 580.M, E of Ukulele, July 15, 1919; *Fosberg* 10040, Puu Kukui, pool, 1700 m., Aug. 24, 1933; *Hitchcock* 15094, N of Kamalo, 4000', Oct. 10, 1916, (US); *Krauss* 480, trail above Haelaau, Puu Kukui, 5000', Sept. 12, 1948; *Krauss* 380, Olinda Flume Line trail, 4300', Sept. 6, 1948; *Krauss* 473, trail above Haelaau, Puu Kukui, 5000', Sept. 12, 1948; *Krauss* 381, stream bed above Olinda trail, 4300', Sept. 6, 1948; *Krauss* 409, trail above Haelaau, Puu Kukui, 4800', Sept. 8, 1948; *Krauss* 415, trail above Haelaau, Puu Kukui, 4500', Sept. 8, 1948; *Krauss*, 427, trail above Haelaau, Puu Kukui, 4800', Sept. 8, 1948; *Rock* 8751, Olinda Waikamoi, Apr. 22, 1911.

HAWAII: *Cramwell* 3456, Kohala Mts. near Kamuela, Sept. 29, 1922, (GB); *Degener* 2216, 17 mi. from Kohala to Waimea, June 31, 1926, (NY); *Degener* 2212B, 17 mi. from Kohala to Waimea, June 31, 1926, (NY), (mixed collection); *Faurie* 1215, Glenwood, May 1907, (KY); *Forbes* 501.H, Kohala Mts., Waimea, Sept. 1911; *Rock*

3170, Paauhau, June 24, 1909; *Rock* 3173, Paauhau No. 1 Stream, 3000', June 24, 1909; *Skottsberg* 705, Kohala Mts. near Kamuela, Sept. 29, 1922, (GO); *Skottsberg* 593, S slope of Mauna Loa above Pahala, Sept. 19, 1922, (GO).

*Carex pluvia* R. Krauss, a member of subgenus *Eucarex*, section *Acutae* Fries, subsection *Cryptocarpae* Tuckerman (Kükenthal 1909: 297), stands close to *Carex alligata* F. Boott. It differs from the latter in the dull membranous to chartaceous bi-convex perigynia, which may bear setae on the rostrum and on the rostrum base, as in *Forbes* 501.H and *Forbes* 580.M. It is often 1–3-nerved from the stipitate base. This species is related to *Carex laciniata* F. Boott. It differs from *Carex laciniata* F. Boott primarily in the lack of the multiveined perigynia and in the more clearly bidentate rostrum; also, the peduncles are shorter and the internodes in the inflorescence are much reduced in *Carex pluvia*. It is usually of smaller stature, about 50 cm. long, rarely reaching 75 cm. Certain specimens have been collected with the intact spikes bearing hundreds of germinated seeds (*Krauss* 380).

The placing of the group as a species seemed at first to be questionable. Inasmuch as *Carex pluvia* and *Carex sandwicensis* were found growing together, especially on Maui, the possibility of wide biotypic variation seemed great. However, the plants growing in the same general areas seemed to have ecologic preferences, *Carex pluvia* in the wet shaded areas, often in running water, and *Carex alligata* in the drier sunny uplands. This suggested that they might be ecologic forms or varieties, but the distinctness of shape and surface of the perigynia, verified by repeated visits to the same plants as they matured, and the lack of intermediate forms between the two, although growing side by side, seem to eliminate this possibility. The distribution also gives some clue as to the constancy of the species. *Carex pluvia* is

found alone on Oahu and together with *Carex alligata* on Maui, Hawaii, and Kauai.

In spite of its distinguishing characters the species is probably a recent one. The differences within the specific limits, especially the occurrence of extremely large though caducous setae on the ridge running into the rostrum, are remarkable and would suggest another species to many taxonomists.

*Carex laxiflora* Lam is an earlier name applied to a different plant; therefore maintaining the epithet of the variety of Kükenthal would create a later homonym. The epithet *pluvia* suggests the habitat in and along watercourses subject to flooding. It is the Latin adjective *pluvius*, meaning wet or rainy.

*Carex pluvia* var. *koolauensis* var. nov.

Figs. 15, 16a–b

A specie differt in squamis radicum 8–12 mm. latis 1–11 cm. longis crassis persistentibus rubris aut purpureis culmis fertilibus 2–4 mm. latis, 50–100 cm. longis erectis striatis, in apicibus scabris ad basim glabris, laminis viridibus sed ad basim, rubris aut purpureis vaginis lignosis rubris aut purpureis, inflorescentis 8–15 cm. longis erectis ramosis 7–11 nodis 103 spiciferis, internodis inferis 2–3 cm. longis superioribus brevioribus, bracteis-laminiferis inferioribus 30–45 cm. longis superioribus brevioribus, pedunculis 3–7 mm. longis in ocreis purpureis lanceolatis inclusis, squamis foeminis utriculis aequantibus carinis dorsalibus 2–3 albi-nervosis in marginibus membranaecis purpureis, utriculis 1–2 mm. latis 3–4 mm. longis incrassatis striatis ovoideis aut anguste oblongi-ovoides purpureis-nigris fulgentibus stipitatis rostris 1 mm. longis bidentis, achaenis biconvexis obovoideis utriculis semi-complentibus rugosis aut glabris aureis.

Differs from the species in the following characters: basal scales 8–12 mm. wide, 1–11 cm. long, coarse, persistent, shiny, red to



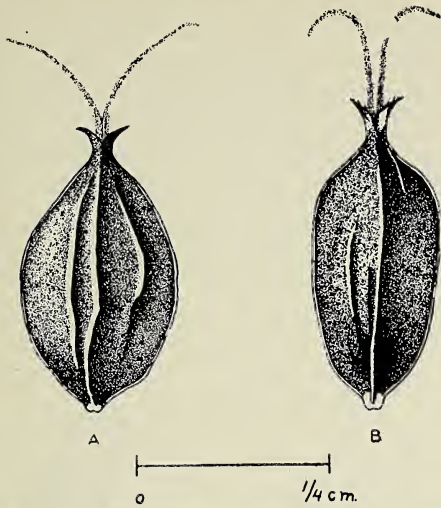


FIG. 16. Perigynia of *Carex pluvia* R. Krauss var. *koolauensis* R. Krauss. a, Hosaka 594; b, St. John 17978.

purple; fertile culm 2–4 mm. wide, 50–100 cm. long, erect, striate, scabrous on the angles above, smooth below; leaves brilliant red to purple at the base, light green above; sheaths ligneous, brilliant red to purple; inflorescence 8–15 cm. long, erect, branching, 1–3 spikes to a node, 7–11 nodes to an inflorescence, the lower 2–3 internodes 2–3 cm. long, the upper much shorter forming a dense head, each node enclosed by a leafy bract, the lower 30–45 cm. long, the upper shorter; peduncles of spikes 3–7 mm. long, enclosed by a purple, lanceolate ochrea; pistillate bracts equalling the perigynia, 2–3 white nerves along the dorsal keel, margins membranous, purple; staminate bracts lanceolate, 2–3 white nerves along the keel, margins membranous, purple; perigynia 1–2 mm. wide, 3–4 mm long, ridged, ovoid or narrowly oblong-obovoid, 1–3 ridged or veined, shiny, purple to black, rostrum 1 mm. long, bidentate, stipitate; achenes bi-convex, obovoid, filling only half of the perigynium, rugose to smooth, yellow.

*Distribution:* Oahu in Zone D<sub>2</sub> of Riperton and Hosaka (1942), the middle forest, in wet areas in turf; usually with grasses.

*Type:* Hosaka 594, Kipapa Gulch, 2,500 feet, July 4, 1932.

#### *Specimens examined*

OAHU: Fosberg 9730, Kipapa Gulch, 850 m., Aug. 6, 1933; Fosberg and Hosaka 13946, head of Kawaiiki Gulch and Kaluanui Gulch, 900 m., May 30, 1937; Hosaka 594 (see type); St. John 17978, Hauula, Castle Trail, 2500', Apr. 25, 1937; Takata, Castle Trail, Kaluanui, 1000', Apr. 25, 1937.

The variety *koolauensis* was first found by Edward Hosaka in 1932. It has been collected since in two other stations on Oahu. The variety shows transition with the species in Fosberg and Hosaka 13946 in that the purple-black covering of the perigynia is fully formed in some and just beginning to form in others. The perigynia are characteristically more narrow and more strongly stipitate than those of the species. The two teeth of the beak are longer and more conspicuously divaricate. With the small number of collections it seems unwise to classify the population as a new species, though its appearance is considerably different. Its rarity, in turf in regions well populated by the species, suggests the possibility that it is a variation resulting from an unusual combination of minor genetic differences as well as of ecological extremes.

*Carex alligata* F. Boott, Illust. Genus *Carex* IV, 129, 1867.

Figs. 17a–f, 18

*Carex sandwicensis* Boeckler, Flora, 265, 1875.

*Carex crustacea* Nelves, Kew Bull. I, 11, 1946.

Rootstocks caespitose; basal scales 8–15 mm. wide, 3–12 cm. long, 3–6 per culm, fibrillose, brown to purple; fertile culm triangular in cross section, 3–4 mm. wide, 60–150 cm. long, erect, striate, scabrous on the angles above, becoming smooth below; leaves 8–15 mm. wide, 20–120 cm. long, 4–8 per fertile culm, erect below, pendent above, V-shaped to flat, shiny, scabrous on the main

veins and margins, tapering, dark green; sheaths 25 cm. long, tight, closed by a brown to red membrane; inflorescence 10–15 cm. long, branching, pendent, 4–6 nodes, one spike per node, internodes 2–3 cm. long at the base shortening toward the apex, each node and peduncle enclosed by a leafy bract 1–30 cm. long, the lowest bracts being the longest; spikes androgynous except the terminal one which is staminate, 3–5 mm. wide, 5–10 cm. long, densely set with fruit, 7–8 ranks of perigynia around the axis; pistillate bracts oblong to obovate, 1.5–2 mm. wide, 3–4 mm. long, short-awned, three green to yellow nerves at the center, margins hyaline, brown to purple; staminate bracts lanceolate, 1 mm. wide, 4–5 mm. long, three center nerves yellow to brown, margins brown to purple; perigynia subspherical-ovoid or even ellipsoid, 2 mm. wide, 2.5 mm. long, lenticular, bi-convex in cross section with a distinct bulge giving one face more convexity than the other, two distinct ridges along the margins from the rostrum to the base, often a third along the bulge, rostrum shallowly bidentate, 5 mm. long, highly polished, smooth, obscurely nerved when immature, light brown to very dark brown; achenes obovoid, lenticular, glabrous to sparsely hirsute, minutely rugose, not filling the perigynium, yellow to brown; style 2–3 mm. long, doubled back against the achene and then passing out of the rostrum, splitting into two stigmas at the apex of the beak, glandular.

*Distribution:* Hawaii, Maui, Molokai, and Kauai in Zones D and E of Ripperton and Hosaka (1942), the middle and upper forest, in open places in the forest, along ditches and roadsides; common.

*Type:* U. S. South Pacific Exploring Expedition under the command of Capt. Wilkes, U. S. N., 1838–42, Sandwich Islands, Hawaii, U. S. National Herb. No. 27224.

#### *Specimens examined*

KAUAI: *Degener* 2208, Waianae Swamp,

June 28, 1926, (NY); *Degener* 2210, Kokee Camp, June 25, 1926, (NY); *Fosberg* 12674, Plateau at the head of Kalalau Valley, 1250 m., Dec. 29, 1935; *Fosberg* 12675, Plateau at the head of Kalalau Valley, 1250 m., Dec. 29, 1935.

MOLOKAI: *Remy* 148, 1851–55, (GH); *Forbes* 438.Mo, Kolapamoa, Aug. 1912.

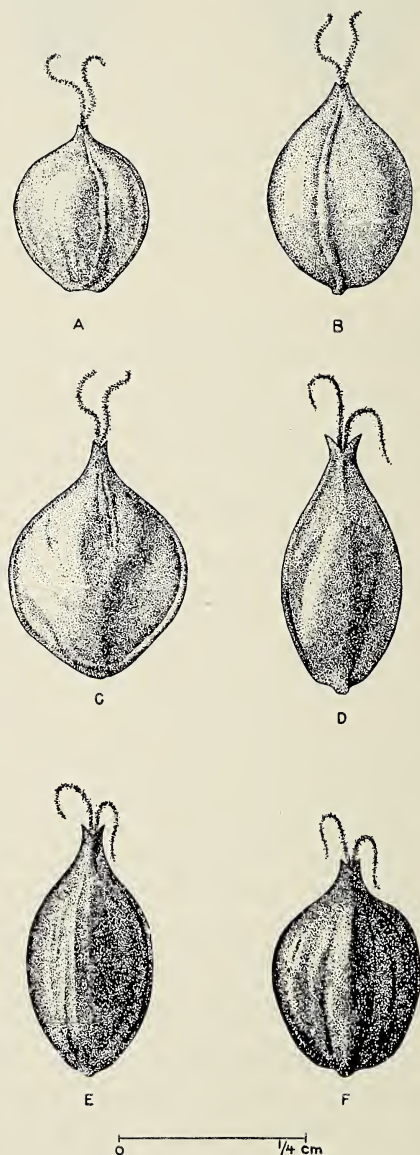


FIG. 17. Perigynia of *Carex alligata* F. Boott. a, *Degener* 8251; b, *Degener* 2213; c, *Krauss* 481; d, *Krauss* 477; e and f, *Fosberg* 12675.



MAUI: *Degener* 8261, Koolau Gap within Haleakala Crater, Aug. 17, 1928, (NY); *Degener* 8256, Olinda Pipe Line Trail, June 14, 1927, (NY); *Degener* 8240, Olinda Pipe Line Trail, July 30, 1927, (NY); *Degener* 8251*b*, Olinda Pipe Line, June 16, 1927, (NY); *Forbes* 692.M, Ukulele, July 1919; *Forbes* 857*a*.M, E of Ukulele, July 20, 1919; *Forbes* 907.M, Ukulele, July 1919; *Forbes* 1168.M, N slope of Haleakala, Aug. 17, 1919; *Hitchcock* 14757, Puu Kukui, Sept. 24–26, 1916, (US); *Hitchcock* 14926, E of Olinda, 4000', Oct. 1, 1916, (US); *Krauss* 338, 339, 340, 353, Draw behind Paliku, 6500', Sept. 3, 1948; *Krauss* 386, Olinda Dam end of Flume Line, 4400', Sept. 6, 1948; *Krauss* 388, Olinda Flume Line, 4300', Sept. 6, 1948; *Krauss* 389, road to Olinda Dam, 4400', Sept. 6, 1948; *Krauss* 395, Olinda Flume Line, 4300', Sept. 6, 1948; *Krauss* 432, trail above Haelaau, Puu Kukui, 3500', Sept. 12, 1948; *Krauss* 477, trail above Haelaau, Puu Kukui, 3700', Sept. 12, 1948; *Krauss* 481, trail above Haelaau, Puu Kukui, 4000', Sept. 12, 1948; *Rock* 8759, Waikamoi Trail, May 14, 1911; *Rock* 8761, Waikamoi Trail, May 14, 1911; *St. John* 10307, Kula, Olinda Pipe Line, 4400', Feb. 11, 1930.

HAWAII: *Degener* 2212*A*, 17 Mi. from Kohala toward Waimea, Aug. 1, 1926, (NY), (mixed collection); *Degener* 2213, 17 mi. trail from Kohala to Waimea, Aug. 14, 1926, (NY); *Degener* 19411, Popalooa, June 7, 1948, (NY); *Faurie* 1221, Mauna Kea, 2000 m., July 1909, (KY); *Faurie* 1280, Halawa, 800 m., June 1909, (KY); *Forbes* 389.H, Kau Desert, Aug. 2, 1911; *Forbes* 803.H, Hale Oloha, June 10, 1915; *Hillebrand* 534, (K); *Hitchcock* 14378, Waimea, Aug. 26, 1916, (US); *Mann & Brigham* 325, high central plateau, 1867, (G, US); *Remy*, (K); *Skottsberg* 593, forest above Pahala, 1000 m., Sept. 19, 1922, (GB); *St. John & R. S. Cowan & D. P. Rodgers* 22400, Saddle Road, Waiakea, S Hilo, 4000',

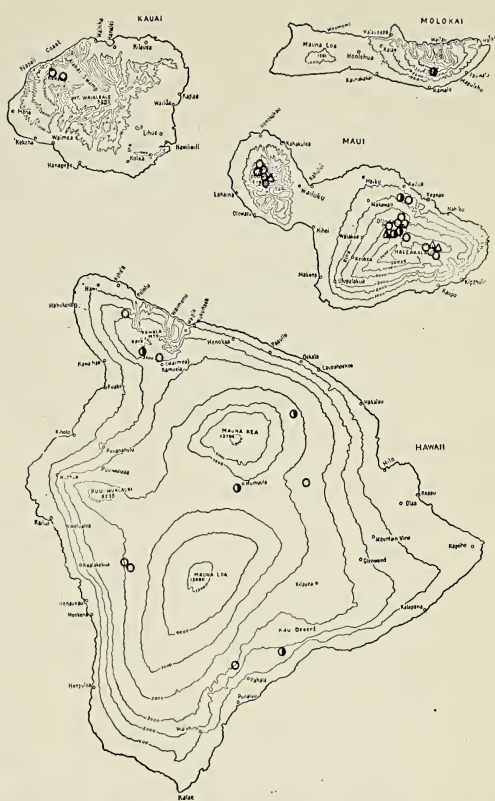


FIG. 18. Distribution of *Carex alligata* F. Boott (indicated by circles) and of *C. alligata* var. *Degeneri* R. Krauss (indicated by triangles).

Dec. 26, 1946; *Wilkes Exped.*, 1838–42, (US); *Wilkes Exped.*, forest above sawmill, (K).

*Carex alligata* Boott is a member of subgenus *Eucarex*, Coss. and Germ., section *Acutae* Fries, and subsection *Cryptocarpae* Tuckerman. It stands by itself within the group. Relationship of this species with the other *Cryptocarpae* in the islands is close but the characters separating them are clear. (See *Carex kauaiensis*, *Carex pluvia*, and *Carex pluvia* var. *koolauensis*.) The species seems to be an old one in the islands and the stock from which it sprang probably gave rise to the other two species and varieties. As mentioned before this group is a variable one and may be confusing. The young perigynia are a light yellow which sometimes turns to a very dark brown. This transition may be ob-

served by placing the perigynia in a moist petri dish for a few days. This variation in color may occur as in *Fosberg* 12675 and 12674, where all gradations may be seen on a single spike, or it may be found without intermediates, the perigynia being not only black or turning black but somewhat oval with exaggerated rostra, as in *Krauss* 476, 479, 478. The species responds with unusual sensitivity to the environment and may develop some of its different forms as a result of recombinations of one or more slightly different mutant genes affecting shape and surface of the perigynia.

*Carex sandwicensis* Boeck. based on *Remy* 148, Molokai, 1851-55 (G), is a later synonym published in 1875 and made by Boeckler apparently without knowledge of the earlier publication of Boott in 1867. It has been accepted and used widely but must be submerged.

*Carex crustacea* Nelmes, represented only by the type, is rather unusual in the great length of the internodes between the spikes and also in the reduced size of the spikes. The more normal internodes are 2-3 cm. long at the base and seldom as long above, as in Nelmes' *Carex crustacea*. It is believed from a study of the population that *Carex crustacea* cannot be maintained as a species. It is regrettable that at this stage in our science a species should be described from one fragmentary specimen and in a few vague words as a footnote to a key.

*Carex Prescottiana* Boott is illustrated in Boott's *Illustrations of the Genus Carex* from a collection of the U. S. Exploring Expedition (the Wilkes Expedition) from "the forest above the sawmill, Hawaii." The specimen secured from Kew has a note as follows:

Laid in from herb. Boott, Oct. 1894. This is the whole Sandwich material which Boott subsequently pasted down in his type cover of *Carex Prescottiana*. From California Boott founded his *Carex Pres-*

*cottiana* on Wall. Col. 3386 and published it in Proc. Linn. Soc., v. I, p. 280. When he got this material from Hawaii he determined it as identical with Wallich n. 3386 and then marked a query against Wallich's locality Nepal. I consider that the Hawaiian plant differs specifically from the Nepal one. It is *Carex sandwicensis*, Boeck.

C. B. Clarke, Oct. 1894

All that remains of this specimen is a packet of one dozen loose fruits. On examination the black spots illustrated in Boott (1867: 45, Pl. 115) prove to be spots of a fungal infection. The veins shown in Boott's illustration are not found in all perigynia and in none as strongly as drawn. The two teeth of the rostrum are distinct in most of the fruits though the infected ones seem to be broken or missing. Clarke's conclusion is valid. The remaining specimens, however, do suggest a gradation into variety *Degeneri* which is found on Maui and Hawaii.

The type material which is figured by Boott is mentioned only as coming from the Wilkes Expedition collections in the district of Waimea, Hawaii. The material from the Wilkes Expedition marked *Carex alligata* Boott is now in the U. S. National Herbarium and is the only specimen which fits Boott's plate. The specimen, although it is the type, is not typical. It is a small young plant with somewhat narrower perigynia than those commonly found. Moreover, the perigynia have become dark although the typical surface persists.

*Carex alligata* Boott var. *Degeneri* var. nov.

Figs. 18, 19a-b

A specie differt in squamis foeminis purpureis aut purpureis-nigris in marginibus glabris aut albo-fimbriati carinis albis centralibus saepe aristatis, utriculis 1-2 mm. longis 2-5 mm. latis ovalibus aut ellipsoideis in lineamenta tenuiter biconvexis incorporis fulvis



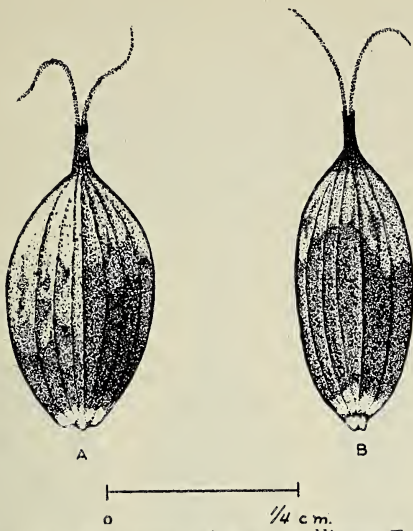


FIG. 19. Perigynia of *Carex alligata* F. Boott var. *Degeneri* R. Krauss. a, b, *Degener* 8253.

purpurei-maculosis, nervosis 5–8 gracilibus basis ad apicos extendentibus breve stipitatis apicibus rostrorum integris aut breve bidentatis oribus glabris aut setaciferis.

Vegetatively showing the same characters as the species but different in the following: pistillate bracts purple-black to black, smooth or white fringed on the margins, white-keeled through the center, prolonged in some to a setaceous awn; perigynia 1–2 mm. long, 3–5 mm. wide, narrow, oval to elliptic in outline, thinly bi-convex, surface yellow-brown splotched with purple, short stipitate, rostrum with an entire or weakly bidentate apex smooth or setaceous at the mouth, 5–8 thin nerves extending from base to the apex.

*Type:* *Forbes* 1189.M, Bog at Waianapanapa, Maui, Aug. 23, 1919.

#### *Specimens examined*

MAUI: *Degener* 8253, Mauka of Olinda on the way to Haleakala, June 15, 1927; *Forbes* 1189.M, Bog at Waianapanapa, Aug. 23, 1919; *Forbes* 1226.M, Waianapanapa, Aug. 23, 1919; *Fosberg* 10026, between Nalakalua and summit of Puu Kukui, 1740 m., Aug. 24, 1933.

This variety has a distinctly veined surface

of the perigynium and an entire or slightly bidentate rostrum. There is a suggestion of the characteristic structure of the variety in certain other of the Maui specimens, especially those collected near Paliku, Maui, indicating a degree of transition. Individual plants give the impression of different species but the presence of intergradations makes a higher category impossible.

#### *Carex kauaiensis* sp. nov.

Figs. 20a–c, 21

*Carex sandwicensis* Boeck. f. *subverticillata* Kükenth. Fedde Rep. XVI, 435, 1920.

Rhizomatis caespitosis, squamis radibus 8–10 mm. latis 2.5–11 cm. longis rubri-aut fusi-lineatis culmis fertilibus triangularis 2.4–4 mm. latis 120–150 cm. longis infra glabris supra scabris erectis, 4–8 laminis 13 mm. latis 150–200 cm. longis erectis in apicibus pendulis crassis in basis glabris in venosis et marginibus superioribus scabris, vaginis membranacis strictis 25 cm. altis deinde partitis inflorescentis 15–20 cm. longis 5–8 mm. latis ramosis 6–7 nodis unispiciferis internodis inferioribus 2–3 cm. longis superioribus brevioribus bractis laminiferis 2–4 mm. latis 3–30 cm. longis nodis inclusis, spicis androgynis praeter terminalis masculis 2–4 mm. latis 8–15 cm. longis pendulis laxe fructiferis utriculis vix basis utriculis superioribus contigendis, pedunculis 1–3 cm. longis ocreis 5–8 mm. longis striatis fissuratis inclusis, utriculis 3.5–6.5 mm. longis 1.5–2 mm. latis ellipsoideis aut obovoideis in rostro breve abrupte, coartato basi lata obtusa aut emarginata purpureis-nigris lucidibus scrobiculatis, costis tres ex rostris descendentibus ad basim et obscurantibus, achaenis obovoideis aureis rugosis triangularibus una latere latiora, stylis in 2 stigmatibus 1 mm. supris rostris divisis.

Rootstocks caespitose; basal scales 8–10 mm. wide, 2.5–11 cm. long, streaked red or brown; fertile culm triangular in cross section,

2.4–4 mm. wide, 120–150 cm. long, stiff, erect, smooth on the lower angles, lightly scabrous above; leaves 13 mm. wide, 150–200 cm. long, 4–8 per culm, erect, pendent at the ends, coarse, dark green, smooth at the base, becoming scabrous along the edges and main vein toward the apex; sheaths closed by a striate membrane to 25 cm. above the base, splitting at maturity, tight, holding the base as a slender unit; inflorescence branching, 15–20 cm. long, 5–8 mm. wide, 6–7 nodes per culm, one spike to a node, internodes 2–3 cm. at the base, shortening to 1 cm. at the apex, each node subtended by a leafy bract 2–4 mm. wide, 3–30 cm. long; spikes androgynous except the terminal one which is staminate, 2–4 mm. wide, 8–15 cm. long, pendent, sparsely set with fruit, the apex of one perigynium scarcely reaching the base of the next above it, peduncles 1–3 cm. long, enclosed by a striate, purple, split ochrea 5–8 mm. long; pistillate bract 1.5–2 mm. wide, 4–5 mm. long, ovate, short-awned, awn and three central veins white to yellow, membranous wings of the bract black to purple-black, waxy, awn 1–2 mm. long, toothed, broad; staminate bracts 1 mm. wide, 6–8 mm. long, lanceolate, short-awned, the awn toothed; perigynia 1.5–2 mm. wide, 3.5–6.5 mm. long, ellipsoid or broadly ellipsoid to obovoid, abruptly narrowed to the short 3–5 mm. bidentate rostrum, the base broad-obtuse or even emarginate, highly polished, black, finely scrobiculate surface with three obscure ridge lines equally radiating from the rostrum disappearing toward the base, triangular in cross section; achenes obovoid, yellow, minutely rugose, triangular in cross section, one side broader than the other two; style splitting into two stigmas 1 mm. above the rostrum, stigmas 1–2 mm. long, glandular, black.

*Distribution:* Kauai only, high bogs in Zones C<sub>2</sub> and D of Ripperton and Hosaka (1942), over 3,000 feet, in extremely wet open forest areas.

*Type:* Rock 9017, Kauluwehi Swamp, 4200', Oct. 1909.

#### *Specimens examined*

KAUAI: *Degener* 2208, Waianae Swamp, Kokee, June 28, 1926, (NY); *Forbes* 419.K, Kaholuamano Swamp, Sept. 1909; *Forbes*

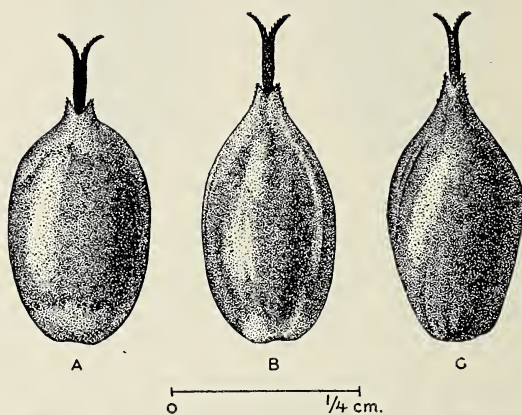


FIG. 20. Perigynia of *Carex kauaiensis* R. Krauss. a, Rock 9017; b, Forbes 419.K; c, Skottsberg 902.

885.K, Alakai Swamp, Waimea Drainage Basin, West Side, July 3–Aug. 18, 1917; *Forbes* 883.K, Waimea Drainage Basin, West Side, Alakai Swamp; *Rock* 9017, Kauluwehi Swamp, 4200', Oct. 1909; *Skottsberg* 902, forest near Alakai Swamp, Oct. 27, 1922, (GO); *St. John* 23047, Alakai Trail at BM 3698 3700', Dec. 25, 1947; *St. John* 23040, Alakai Trail NE of second fork of Kawaikoi Stream, Dec. 25, 1947; *St. John* 23041, Alakai Trail 3900', Dec. 25, 1947; *St. John* 22926, Ridge SW of Pihea, 4000', Dec. 22, 1947.

*Carex kauaiensis* is a member of the subgenus *Eucarex*, section *Acutae*, subsection *Cryptocarpae*. It appears to be a recent species evolved from the line leading to *Carex alligata*. It differs from this in the pronounced smooth, polished, non-stipitate perigynium, the long-awned bracts, and the triangular achene as well as the long internodes between points of perigynial attachment on the rachis.





FIG. 21. Distribution of *Carex kaniensis* R. Krauss.

Kükenthal's description of forma *subverticillata* is, "Spiculae priores sed utriculi 2–4 fere verticillatum dispositi nigricomtes." He cites as his type *Rock* 8017 with precisely the same data as those given on *Rock* 9017 at the Bishop Museum. It is to be assumed that the 8 is a typographical error.

Dr. Carl Skottsberg has written that he also considers this a new species. He suggested the name *kauaiensis*, which is being adopted.

So far the species has been found only in the high bogs of Kauai. It is doubtful if it has spread to any other of the islands.

## Nomen Inquirendum

Kükenthal (1909: 133) describes a new species, *Carex flaviceps*, collected on Oahu by Eschscholtz and deposited in the herbarium of the Botanical Garden in Leningrad, Russia. Requests for the loan of material from that source have not been answered. From the description the appearance of the plant is that of *Carex macloviana* except that it is androgynous and not gynaeceandrous. Kükenthal mentions that the specimen is immature. The two characters are of primary importance in the subgenus *Vigneae* and one would not expect Kükenthal to make such a fundamental mistake. The locality, Oahu, also lends doubt to the supposition that the plant is *Carex macloviana*. Until such time as col-

lections from the Russian herbaria are available the real identity of *Carex flaviceps* Kükenth. must remain a mystery.

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## NOTES

### Examination of Hawaiian Marine Crustaceans for Gregarines

During the months of February and March, 1949, the writer had the opportunity to examine for gregarines 149 specimens belonging to 33 species of Hawaiian marine Crustacea. The following species were examined:

*Balanus amphitrite*, *Balanus eburneus*, *Balanus* sp., *Calappa hepatica*, *Calliactis armilatus*, *Crangon pacificus*, *Crangon ventrosus*, *Crangon paragracilis*, *Cyclograpsus henshawi*, *Dardanus asper*, *Dardanus punctulatus*, *Emerita pacifica*, *Grapsus grapsus tenuicrustatus*, *Lepas anatifera*, *Lissocarcinus orbicularis*, *Metapograpsus messor*, *Ocypode ceratophthalmia*, *Ocypode laevis*, *Pachygrapsus plicatus*, *Panulirus japonicus*, *Paraxanthias notatus*, *Percnon planissimum*, *Plagusia depressa tuberculata*, *Platypodia (eydouxii ?)*, *Portunus sanguinolentus*, *Scylla serrata*, *Sesarma obtusifrons*, *Simocarcinus simplex*, *Thalamita edwardsi*, *Thalamita integra*, *Thalamita picta*, *Trapezia maculata*, a xanthid.

No gregarines were found in any of the species examined except in the digestive tract of *Balanus eburneus*; these in all probability are specimens of *Cephaloidophora communis* Mavrodiadi, described elsewhere from *Balanus eburneus* and from other members of the genus *Balanus*. Since *B. eburneus* has a very wide distribution over the world, the presence of *C. communis* is not surprising. It is surprising, however, not to find gregarines in any other of the species studied. In addition to

the digestive cavity, the caeca, liver, gills, and hairs of the abdomen and of abdominal appendages were examined. Of the other genera listed, gregarines have been found elsewhere, sometimes in a large percentage of specimens, in *Emerita*, *Pachygrapsus*, *Calappa*, and *Portunus*. The first two are infected on the Pacific coast of North America. Furthermore, some of the Hawaiian forms belong to genera very close to those carrying gregarines in various other parts of the world.

A parallel situation has recently been described by McConnaughey (Calif. Univ., Pubs., Zool., 55:1-34, 1949), who found none of the octopi he examined in Hawaii positive for dicyemids, although there is practically 100 per cent infection of octopi on the Pacific coast of North America.

Although these data drawn from the distribution of certain marine endoparasitic Protozoa are fragmentary, one possible interpretation is the relative independence of the Hawaiian invertebrate hosts from their counterparts on the Pacific coast of North America.

The author wishes to express his appreciation to the Department of Zoology and Entomology of the University of Hawaii, Dr. Robert Hiatt, Chairman, and to Mr. Spencer Tinker of the Honolulu Aquarium for the many courtesies extended.—Gordon H. Ball, Department of Zoology, University of California at Los Angeles.

## News Notes

Dr. L. D. Tuthill, Editor-in-Chief of *Pacific Science* and Professor of Entomology at the University of Hawaii, will leave with his family early in July, 1950, for a year of research study in New Zealand. His studies, supported by a research grant under the terms of the Fulbright Act, will be concerned with the Psyllidae of New Zealand. During his absence Dr. O. A. Bushnell, Associate Professor of Bacteriology, and Dr. E. G. Smith, Assistant Professor of Chemistry, at the University of Hawaii, will serve as editors of *Pacific Science*.

Following an agreement reached at the Seventh Pacific Science Congress in New Zealand last year, a permanent Secretariat of the Pacific Science Association has been established in Honolulu, Hawaii, with headquarters at the Bernice P. Bishop Museum. The Secretariat officers are: Loring G. Hudson of Honolulu, executive secretary, and Brenda Bishop of New Zealand, assistant secretary.

The principal functions of the Secretariat are defined as follows:

To assist governments, institutions, and individuals as well as Standing Committees of the Pacific Science Association in the implementation of resolutions and recommendations adopted by Pacific Sciences Congresses.

To serve as a central office for the Pacific Science Council especially during the intervening period between Congresses.

To serve as an information dissemination center in Pacific science matters.

To assist in maintaining a continuity in the relationship between the Pacific Science Association and such international agencies as the specialized agencies of United Nations, and South Pacific Commission.

H. R. Joesting and J. H. Swartz of the Geophysics Branch of the U. S. Geological Survey, and R. E. Wilcox of the Volcano Investigations Unit, spent the first 3 weeks of February at the Hawaiian Volcano Observatory of the Survey in Hawaii National Park setting up procedures to be followed in a program of magnetic observations, calibrating instruments, and instructing Observatory personnel in their use.

During February and early March, 29 stations were established around and in Kilauea caldera and along the road to the Mauna Loa seismograph. At each station concrete blocks were built on which to set up the tripod of the magnetometer. It is planned to occupy each of the stations at least once a month, and oftener if possible. Periodic readings will be taken to determine the variation in the vertical component of the earth's magnetic field, particularly the changes in differences between the various stations.

HIATT, ROBERT W. *A Directory of Marine Laboratories of the United States and Canada*. Contribution No. 4, Hawaii Marine Laboratory. University of Hawaii, Honolulu, T. H. 70 pp., mimeographed. Available from the Director, Hawaii Marine Laboratory. A list of the major marine laboratories of the United States and Canada, giving for each institution its location, director, sources of financial support, season of operation, function, capacity, facilities for research, estimated expenses concerned with laboratory accommodations and with room and board, and the members of its staff.

SPOEHR, ALEXANDER. *Majuro, A Village in the Marshall Islands*. Fieldiana: Anthropology, Volume 39, November, 1949. Chicago Natural History Museum, Chicago, Ill. 266 pp., 50 figs., 11 maps. \$3.50. An extensive study of the contemporary formal social organization of a Marshallese village.



# PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



IN THIS ISSUE: Suessenguth—*Flora of Australia and Antiquity of Angiosperms* • Gosline—*Osteology and Relationships of Kaupichthys diodontus* • Sherman—*Hawaiian Ferruginous Laterite Crusts* • Lange—*Giant African Snail on Saipan* • Takashima—*Amblypygi Found in Territories Adjacent to Japan* • St. John—*Subgenera of Dubautia* • Milliron—*Species of Pulvilligera from the Southwest Pacific* • Dellow—*Inter-tidal Ecology at Narrow Neck Reef, N. Z.* • NOTES • INDEX

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*Original copy and one carbon copy* of manuscript should be submitted. The author should retain a carbon copy. Although due care will be taken, the editors cannot be responsible for loss of manuscripts.

*Introduction and summary.* It is desirable to state  
(Continued on inside back cover)



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# The Flora of Australia as a Measure of the Antiquity of the Angiosperms

KARL SUESSENGUTH<sup>1</sup>

## INTRODUCTION

IF ONE INTENDS to consider as difficult a problem as the early history of a large land area, Australia would seem to be particularly suitable for such a study: its long geographic isolation and the great number of scientific investigations to which it has been subjected make it a natural choice.

Australia's land connection with the island groups of Malaysia (except for New Guinea) was ended in the Upper Cretaceous period. According to physicists' calculations, based on the rates of disintegration of radioactive elements, about 30–40 million years have passed since the Eocene epoch in early Cenozoic time. Inasmuch as the Upper Cretaceous period occurred before the Eocene epoch, it can be concluded that, on the whole, the Australian flora and fauna have remained undisturbed for an extremely long time. Under these circumstances of isolation, ancient forms of plant and animal life have been preserved, while, during the long periods since the isolation began, new species of plants and animals have developed from them as well. It must not be forgotten, however, that immigration also has occurred, introducing new species into Australia's plant and animal life since the beginning of its geographic isolation.

The many investigations into the animal life of Australia have given unequivocal evidence of the continent's isolation. Today the most primitive mammals—the Monotremata (*Ornithodelphia*) and the species of *Echidna*, *Proechidna*, and *Ornithorhynchus*—appear

only in Australia and in New Guinea. These mammals resemble reptiles more than any of the other mammals because they lay eggs, have a cloaca, and still possess the number of shoulder bones of primitive animals. As fossil evidence has shown, their ancestors appeared during the Triassic formation, to become, in fact, the first of the mammals. They increased in number during the Jurassic period, but, to a great extent, they died out as early as the Eocene epoch. In Australia, however, some of these primitive mammals have survived to this day, affording us illustration of the concept of "endemism by conservation."

The marsupials, too, are notably typical of Australia. They are not limited to Australia, for there are opossums in North and South America, and Chironectides in South America; but the great majority of the marsupials is found only in Australia. They have developed there, it is interesting to observe, in a manner analogous to the development of placental mammals of the other continents, notably the carnivores, rodents, insectivores, and ungulates.

The survival of the Monotremata and of the Marsupialia can be attributed to the fact that, before man's appearance on the Australian continent, no other placental mammals existed in Australia to prey upon them. There were only mice, which sometimes wandered on driftwood from island to island, and bats; but these were not significant enemies. (It may be possible, of course, that the mice and the bats first arrived in Australia in times subsequent to the Upper Cretaceous period and, therefore, subsequent to the be-

<sup>1</sup>Botanische Staatssammlung, Munich 38, Germany. Manuscript received November 20, 1948.

ginning of Australia's geographic isolation.) As far as the dingo is concerned, it is supposed that aboriginal Austral inhabitants entering Australia from Malaysia were the first to bring this animal to the southern continent.

It is also pertinent to our thesis to note that zoologists believe that some of the opossums (*Caenolestes*) migrated to North America from South America. Fossils of *Marsupialia* have been found in Europe and in North and South America, an indication that they must have been distributed over vast regions of the earth. The *Marsupialia* have survived chiefly in Australia, and for this reason Australia today has the oldest and most primitive mammal types in the world.

Now because, geologically speaking, mammals and angiosperms are of about the same age, it is natural to ask if the oldest and most primitive of the flowering plants are also to be found in Australia today. The answer to this question would help us to determine the antiquity of the angiosperms.

This is a question that is difficult to answer, if only because botanists are not in agreement on the most primitive species of angiosperms. This one question asks other questions: If the earliest species of angiosperms could be defined, would it be found that they exist preeminently or even exclusively in Australia? Or, if the earliest species cannot be defined, is it possible to determine, from the Australian flora of today, which are the most primitive species of angiosperms that have succeeded in persisting until this time? These are the problems to be investigated in this paper.

#### WHAT ARE THE MOST PRIMITIVE FAMILIES OF THE FLOWERING PLANTS?

As every botanist knows, the question of primitiveness in flowering plants is a controversial one. Some think that certain species of the *Monochlamydeae* are the most primi-

tive, while others think that the *Polycarpiceae* among the *Choripetales* are the most ancient. Once, even certain of the *Monocotyledones* (the *Pandanales*) were considered for the distinction, although this claim, of course, could not be proved by any significant arguments. Inasmuch as this is hardly the place for a discussion of the phylogenetic criteria by which plants are judged, the more pertinent portions of my book, *Neue Ziele der Botanik* (1938), are suggested for reference.

If, in our search for the oldest angiosperms, and in our analysis of the Australian flora, we hold the opinion that those families which are put at the head of the *Monochlamydeae* in the Engler and Prantl system of classification are the ones which show the most primitive characteristics, we should be supported in this assumption by the *Casuarinaceae* found in Australia. In their original distribution they extended from Sumatra to the Philippines, New Caledonia, and the Fiji archipelago (Diels, 1926), and to Tahiti, the Austral Islands, and the Marquesas (Brown, 1935). As yet, however, there is no reliable basis for the hypothesis that the *Casuarinaceae* are more nearly related to the *Gymnospermae* than is any other family of the *Angiospermae*. Neither can this supposition be proved for the *Proteaceae* and the *Balanopsidaceae*, which are also placed at the beginning of the *Monochlamydeae* in the Engler and Prantl taxonomic system. In Australia more than half of all of the species of *Monochlamydeae* are *Proteaceae* (about 600 species), although the family has extended to southern Africa, southern Asia, and South America (Vester, 1940). The species of *Proteaceae* are almost exclusively ligneous plants, which would indicate that, phylogenetically, they are rather an old group, but in the absence of paleontological evidence we cannot be certain that these species are really older than many others we might consider, so we have to be content only with supposing that they *might* be.



On the other hand, if we hold the opinion, as many botanists do, that the Polycarpiceae are the most primitive of the Angiospermae, we should find that only two very small families of Polycarpiceae are endemic in Australia: the Eupomatiaceae and the Himantandraceae, which are related to the Eupomatiaceae, but which possess neither calyx nor corolla (Diels, 1919: 126 *et seq.*). The other families of Polycarpiceae are not well represented in Australia: the Magnoliaceae afford only 4 species, the Annonaceae 18, the Nymphaeaceae 5, the Ranunculaceae 17, and the Myristicaceae 1. In view of these facts, it cannot be claimed that the Polycarpiceae are the most primitive of angiosperms in Australia and that a comparison with the preservation of the earliest mammals could be made.

This brief appraisal is enough to show that the angiosperms which most botanists consider to be the oldest of flowering plants (Polycarpiceae) do not exist exclusively or pre-eminently in Australia. But in the information we have learned about the Casuarinaceae and the Proteaceae we may have found certain clues which will be of value later when we investigate their degree of primitiveness.

WHICH SPECIES OF ANGIOSPERMS  
PERSISTING IN AUSTRALIA ARE  
THE MOST PRIMITIVE?

Now we can set about answering the second question, inquiring into the conclusions which can be drawn from a study of the history of the Australian flora. At first it may seem questionable in itself to compare the early histories of flowering plants with those of mammals, particularly when it is realized that the conditions governing their migrations were quite different. We assume that those mammals living in Australia during the Upper Cretaceous period have been isolated since that time because of the continent's isolation, and that only rarely have they been joined by later immigrants. Can the same assumption be made for the flower-

ing plants? Or may those various plant species now found in Australia have migrated to the continent since its separation because they—or rather, their seeds—could cross the ocean gap while the animals were not able to do so?

To obtain a general view of the whole flora of Australia, let us consider the catalogue of F. von Mueller, his *Census of Australian Plants* (1889). Because of the recent advances in our knowledge, Mueller's list is neither complete nor infallible, yet it is not likely that the proportions of the numbers of species within large groups and of the endemic species have changed significantly since that time. Therefore we may use the *Census* without hesitation, all the more necessarily because there does not exist a later catalogue for the whole Australian territory (including Tasmania but not New Zealand).

Mueller's catalogue lists 8,842 species, and, because it does not mention those species introduced in recent times (since about 1800), it is well fitted for our purpose. Of these 8,842 species, 7,734 (that is, 87.5 per cent) are endemic in the larger sense of the word—that is to say, they are found in Australia itself but may also extend to New Zealand and to parts of Polynesia as well. The percentage of endemism is extremely high.

Table 1 may serve for comparison of the percentage of endemic plants found in Australia with those found in other parts of the world.

As a matter of fact, it is probable that among the 8,842 species listed in Mueller's *Census of Australian Plants* there may be a great many species which were introduced by man, although this hypothesis cannot be substantiated in its details. If this is true, however, the percentage of endemism in Australia would be even higher than it is here calculated.

There is no doubt but that the longer a country has been isolated the more endemics

TABLE 1  
REPRESENTATION OF ENDEMIC PLANTS IN  
AUSTRALIA AND IN OTHER PARTS  
OF THE WORLD

REGION	APPROXIMATE PERCENTAGE OF ENDEMIC PLANTS	REFERENCE
Australia	87.5	calculated from Mueller, 1889.
New Zealand	73	calculated from Cheeseman, 1925.
Hawaii	90	according to St. John, 1946.
Galapagos	40	calculated from Stewart, 1911.
Sokotra	33	according to Drude, 1896.
Balkans	26	calculated from Ha- yek and Markgraf, 1927-1933, and from Turrill, 1929.
Iceland	0	calculated from Os- tenfeld and Grøntved, 1934.

For statements about smaller islands, see O. Drude, *loc. cit.*

it shows; and we may assume that, other conditions being equal, the percentage of its endemism would enable us to measure the length of its period of isolation. Scandinavia, for example, has very few endemics (and these are "weak" endemics in the systematic sense) because there was not enough time for it to be overgrown with flowering plants be-

fore the sparse soil-cover left by the retreating glaciers was removed by erosion, and because the short period during which alluvial soil has been collecting since glaciation has not been long enough for the development of many new species. It is true, of course, that Scandinavia can hardly be compared with Australia, inasmuch as the prevailing temperatures in Scandinavia are not at all favorable for the formation of new species (Sternier, 1943: 84).

Even if we considered as not being endemic to Australia those plants which are also found in New Zealand and in Polynesia, there remain, nevertheless, 7,501 species, or 84.8 per cent, which are limited to continental Australia and Tasmania. Obviously the reduction in number is a minor one.

An appreciation of the manner of the distribution of endemic species among the larger plant groups of the Australian flora will be gained from Table 2, which shows that among the Angiospermae, at least, the endemic species are quite equally distributed among the three groups into which the angiosperms are divided, with 89.3 per cent for the Sympetalae, 90.2 per cent for the Dialypetalae, and 92.9 per cent for the Monochlamydeae. This high number of endemics is not shared by the Monocotyledones, among which only 79.7 per cent of the species are

TABLE 2  
DISTRIBUTION OF ENDEMIC SPECIES AMONG THE LARGER PLANT GROUPS  
OF THE AUSTRALIAN FLORA

PLANT GROUP	TOTAL NUMBER OF SPECIES IN GROUP	PERCENTAGE OF WHOLE FLORA REPRESENTED BY GROUP	NUMBER OF ENDEMIC SPECIES IN GROUP	PERCENTAGE OF TOTAL NUMBER OF ENDEMIC SPECIES IN GROUP
Pteridophytac	244	2.7	124	50.8
Gymnospermae	43	0.5	43	100.0
Monochlamydeac	1,130	12.8	1,050	92.9
Dialypetalac	3,641	41.2	3,286	90.2
Sympetalac	2,229	25.2	1,991	89.3
Monocotyledones	1,555	19.6	1,240	79.7
Totals	8,842	100.0	7,734	87.5 of the total number



endemic. Relatively speaking, they show the smallest number of endemics among the angiosperms, which is rather an interesting fact, inasmuch as in the flora of European countries a certain parallel can be found for these values (Schmidt, 1945).

The smaller percentage of endemics among the Pteridophytae may be explained by the fact that the ferns are more readily disseminated over greater distances by means of their spores. It may be that in this manner many species of ferns immigrated into Australia, or emigrated from it, after its geographical isolation had begun. The same supposition is valid for many species of the Gramineae and for the Cyperaceae among the Monocotyledones.

When we consider the great number of endemics present in the Australian flora, we are tempted to jump to the important conclusion that, in later times, only an inconsiderable migration of plants took place into Australia from abroad. If there had been any considerable degree of migration, we should be able to find the species of plants now living in Australia spread over other continents as well, and especially over Malaysia. Actually, however, they are not so widely distributed, but are confined as endemics to Australia. The evidence is such that we may safely conclude, therefore, that a pronounced development of species took place on the Australian continent *after* the geographical isolation had begun. But, if few species have migrated into Australia from abroad over such a very long time (except in the cases of the Pteridophytae, which show the fewest endemics), is it not probable that all of the types which evolved into endemic species were already in existence *before* the period of geographical isolation, that is, during the Upper Cretaceous period? Did the numerous representatives of the characteristic families of the Australian flora already flourish in those ancient times? Was the Australian flora of those days similar, at least in its families,

to the Australian flora as it is now? Above all, did all of the many families of the Australian flora exist then as they do now? These questions are not easy to answer, and before investigating them it will be useful to give a rather detailed account of the Australian flora itself.

To begin with, it must be accepted that the evolution of the *families* of the flowering plants had begun in times earlier than those of the Upper Cretaceous period, for only a very few endemic families are found in Australia, and these have only a very few species in them. These families are the Akaniaceae, Balanopsidaceae (which also appears in New Guinea), Brunoniaceae, Byblidaceae, Cephalotaceae, and Tremandraceae. These are the only families that have developed endemically in Australia since the Upper Cretaceous period, although they might possibly have been preserved in Australia from times even more ancient than the Upper Cretaceous; since that period there has not been time enough for a further evolution of families. From this evidence we can conclude that it is very likely that the primitive ancestral types of the other, much larger, families of the Australian flora existed during the Upper Cretaceous period. If they had immigrated into Australia after Upper Cretaceous time—which is a possibility we naturally have to take into consideration—then they ought to be found in other parts of the world as well. We shall learn later in detail how far this is true. But, in any event, we must not assume that the six endemic Australian families also existed, at one time, in other parts of the world, only to die out later in those places, so that now they are native to Australia alone. We must be cautious with this kind of conclusion, a lesson which has been made obvious by the example of the mammals of New Zealand, referred to by Diels (1897) in his work on the vegetative biology of New Zealand. We shall return to this matter later in this paper.

According to A. Engler (1882), 425 of the 1,393 genera of the Australian flora—that is, 30.5 per cent—are endemic. This is a statement of great importance, for from it we learn that the time interval between the Upper Cretaceous period and the present time has been sufficient for the creation of a great number of new genera—almost a third of the genera found in Australia—or for the conservation in Australia of a part of them while in other continents they have become extinct. It has already been stated that the same suppositions are valid for 90 per cent of all the Australian species. In short, the period from Upper Cretaceous time until the present has been long enough to create, or, exclusively, to conserve, 30.5 per cent of the *genera* and at least 90 per cent of the *species* of the Australian flora. On the other hand, it has not been long enough a time to permit the creation, or the exclusive conservation, of very many of the families of the Australian flora, particularly of the larger families.

It is interesting, for the sake of comparisons not unimportant to the arrival at a conclusion, to see how the species of the larger groups are distributed in other parts of the world. According to Hégi's *Flora* (1906–1931), the larger groups of plants are represented in central Europe—Germany, Austria, and Switzerland—by the numbers presented

in column 1 of Table 3. These figures are converted, in column 2, into percentage values which can be compared with the figures for the same plant groups in Australia (column 3).

In several of these groups—the Pteridophytae, the Gymnospermae, and the Monochlamydeae—the percentage values for Australia do not differ much from those of central Europe. In Australia the Monocotyledones and the Sympetalae appear somewhat less frequently than they do in Europe; while the Dialypetales are found somewhat more frequently in Australia than in central Europe.

In R. Mansfeld's catalogue of ferns and flowering plants (1940), the figures given for that part of central Europe included in Germany, Austria, Bohemia, and Moravia are presented in Table 4.

In northern Europe the Monocotyledones are even more plentiful. In England they form 25.3 per cent of the flora (Druce, 1932); in Iceland and the Faroes, 30.8 per cent (Ostenfeld, 1934); in Greenland, 31.2 per cent (Ostenfeld, 1926); in Novaya Zemlya, 33.3 per cent (Ekstam, 1897); and in Spitzbergen, 31.2 per cent (Nathorst, 1883). In Portugal the Monocotyledones form 20.3 per cent of the flora (Palhinha, 1939); in Italy, 18.6 per cent (Buscalione and Muscatello, 1911–1913); in the Balkans, 16.3 per cent (calculated from Hayek and Markgraf, 1927–1933); and in the territory of the Aegaeen islands, 17.5 per cent (calculated from Rechinger, 1943). It becomes apparent, then, that the number of species of Monocotyledones is greater in northern Europe than it is in southern Europe.

With the Sympetalae quite the opposite representation is found: the northern countries have fewer of these, the southern countries have more: Spitzbergen has 13.5 per cent; Novaya Zemlya, 16.5 per cent; Greenland, 21.1 per cent; the Faroes, 25.5 per cent; England, 25.4 per cent; Germany, 29.5

TABLE 3  
REPRESENTATION OF ENDEMIC SPECIES AMONG  
THE LARGER PLANT GROUPS OF CENTRAL  
EUROPE AND AUSTRALIA

PLANT GROUP	NUMBER OF SPECIES*	PERCENT- AGE OF "HIGHER FLORA"	COM- PARABLE FIGURES FOR AUSTRALIA
Pteridophytae	74	2.3	2.8
Gymnospermae	11	0.3	0.5
Monochlamydeae	355	11.2	12.8
Dialypetalae	1,043	32.9	41.2
Sympetalae	1,042	32.8	25.2
Monocotyledones	648	20.4	17.6

\* According to Hégi (1906–1931).



TABLE 4  
REPRESENTATION OF ENDEMIC SPECIES AMONG THE LARGER PLANT GROUPS OF CENTRAL  
EUROPE, THE AEGEAN ISLANDS, AND PORTUGAL

PLANT GROUP	CENTRAL EUROPE*		AEGEAN ISLANDS†		PORTUGAL‡	
	NUMBER OF SPECIES	PERCENTAGE OF HIGHER FLORA	NUMBER OF SPECIES	PERCENTAGE OF HIGHER FLORA	NUMBER OF SPECIES	PERCENTAGE OF HIGHER FLORA
Pteridophytae	73	2.3	41	1.2	51	1.9
Gymnospermae	12	0.4	18	0.5	12	0.4
Monochlamydeae	332	10.4	368	11.2	305	11.0
Dialypetalae	1,119	35.2	1,154	35.0	994	36.0
Sympetalae	998	31.4	1,138	34.6	843	30.5
Monocotyledones	645	20.3	574	17.5	557	20.2
Totals	3,179		3,293		2,762	

\*According to Mansfeld (1940). The unimportant differences between Hegi's figures and Mansfeld's may be ascribed to differences in criteria for the recognition of species as well as to the fact that Hegi's *Flora* included Switzerland and the South Tyrol while Mansfeld's did not.

†In his *Flora Aegaea*, Rechinger (1943) covers the territory of the Aegaeen islands from Chalkidike in the north to Rhodes and Candia in the south.

‡The figures for Portugal are given by Ruy Telles Palhinha in his *Flora de Portugal* (1939).

per cent; Portugal, 30.5 per cent; Switzerland, 30.5 per cent; France, 31.2 per cent; Tyrol (including South Tyrol), 33.7 per cent; the Aegaeen islands, 34.6 per cent; Italy, 35.7 per cent; the Balkan countries, 37.4 per cent. (These calculations are taken from A. Schmidt, 1944.)

When the figures for the endemics of Australia are compared with the figures for those parts of Europe which are rich in endemic plants, the contrasts are even more pronounced (Table 5).

From these comparisons we learn that endemic species of the Sympetalae are much more numerous in southern Europe than they are in Australia, and that, at the least, the centers of development of the polyphyletic Sympetalae are not likely to have been located in Australia. If they had been, the percentages of representation would have been reversed.

NUMBERS OF SPECIES IN FAMILIES

According to Mueller's figures (1889), which are approximately correct even today, the most important families in Australia,

with respect to the numbers of their species, are these:

FAMILY	NUMBER OF SPECIES
Leguminosae . . . . .	1,065
Myrtaceae . . . . .	663
Proteaceae . . . . .	597
Compositae . . . . .	539
Cyperaceae . . . . .	380
Gramineae . . . . .	345
Epacridaceae . . . . .	275
Orchidaceae . . . . .	272
Euphorbiaceae . . . . .	226
Goodeniaceae . . . . .	220
Rutaceae . . . . .	190

These eleven families, with a total of 4,372 species, include more than half of all the Australian phanerogams, of which there are 8,555 species. It is worth noting how remarkably the Leguminosae, Myrtaceae, Compositae, and Orchidaceae have developed. As we know, these families are by no means primitive. In this way the plants of the present Australian flora give evidence that their ancestors (related systematically) must have been well-developed at the time of the Upper Cretaceous period and even before.

The percentages of the endemic species in these 11 Australian families are tabulated as follows:

FAMILY	PERCENTAGE OF ENDEMIC SPECIES IN AUSTRALIA
Proteaceae . . . . .	100
Epacridaceae . . . . .	100
Goodeniaceae . . . . .	99.9
Myrtaceae . . . . .	98.3
(including all Leptospermoideae-Chamaelaucieae, all Leptospermoideae-Leptospermeae-Calothamniinae, and all Leptospermoideae-Backhousiinae)	
Rutaceae . . . . .	97.4
Orchidaceae . . . . .	94.8
Compositae . . . . .	91.5
Leguminosae . . . . .	90.6
(including all Papilionaceae-Genisteae-Bossiaeiinae)	
Euphorbiaceae . . . . .	88.0
Cyperaceae . . . . .	70.3
Gramineae . . . . .	69.3

Of the larger families, 13 have only one species which has extended its range beyond Australia to other countries; these families are listed here, together with the number of species in each family which are found only in Australia:

FAMILY	NUMBER OF SPECIES IN AUSTRALIA
Myoporaceae . . . . .	76
Haemodoraceae . . . . .	66
Restionaceae . . . . .	93
Dilleniaceae . . . . .	95
Saxifragaceae . . . . .	35
Magnoliaceae . . . . .	18
Tremandraceae . . . . .	17
Annonaceae . . . . .	16
Stackhousiaceae . . . . .	13
Coniferae . . . . .	29
Cycadaceae . . . . .	14
Casuarinaceae . . . . .	24
Pittosporaceae . . . . .	40

The Chenopodiaceae, with 111 species in Australia; the Hallorhagidaceae, with 58 species in Australia; and the Santalaceae, with 43 species in Australia, each has only two species which extend beyond the continent, and the Amaranthaceae, with 100 Australian species, has five species which extend their range beyond Australia to New Zealand and Polynesia. Of the smaller families, many have species appearing in territories other than the Australian, and are therefore without value in evaluating endemism in Australia:

FAMILY	NUMBER OF SPECIES IN AUSTRALIA	OUTSIDE AUSTRALIA
Nymphaeaceae . . . . .	5	4 or 5
Guttiferae . . . . .	4	3
Geraniaceae . . . . .	8	5
Convolvulaceae . . . . .	70	33
Lythraceae . . . . .	19	12
Onagraceae . . . . .	5	3
Rhizophoraceae . . . . .	7	7
Cucurbitaceae . . . . .	28	13
Hydrocharitaceae . . . . .	9	7
Lemnaceae . . . . .	6	6
Najadaceae	} . . . 36	20
Potamogetonaceae		
Aponogetonaceae		

Many others of the smaller families might be added to this list, to support this contention.

THE PHYLOGENETIC AGE OF  
SYSTEMATIC GROUPS

Let us turn now to another question which is more easily answered: Do there exist, among the families of Australian plants, any

TABLE 5  
COMPARISON OF PERCENTAGES OF ENDEMIC SPECIES IN THE HIGHER PLANT GROUPS OF AUSTRALIA WITH THOSE OF SOUTHERN EUROPE

PLANT GROUP	AUSTRALIA	ITALY	THE BALKANS	SARDINIA
Pteridophytæ	1.6	0.5	0.0	4.2
Gymnospermae	0.5	0.0	0.2	0.0
Monochlamydeae	13.6	2.0	11.8	0.0
Dialypetalae	42.5	35.1	28.8	29.8
Sympetalae	25.8	56.4	49.9	55.3
Monocotyledones	16.0	5.9	9.3	10.6



of the larger systematic groups which are of very ancient age? The criteria for the recognition of phylogenetically old and new characteristics have been treated at length in my book (Suessenguth, 1938: 19 *et seq.*).

Let us consider the Leguminosae first. Among the members of the subfamily Mimosoideae the most important genus in Australia is *Acacia*, which has more than 300 Australian species. The rest of the genera of the Mimosoideae in Australia number only about 23 species.

Is the genus *Acacia*, then, an old or a new genus among the Mimosoideae? If we accept the general phylogenetic principle that free stamens are more primitive than fused stamens, and if we agree that the group of species with numerous stamens (now classified in the tribes Ingeae and Acacieae) is older than the group of species which have 10 or fewer than 10 stamens (now classified in the tribes Eumimoseae, Adenanthereae, Piptadenieae, and Parkieae), then we must conclude that the species of the tribe Acacieae, with their free stamens, are more primitive than are the more or less synantherous species of the tribes Ingeae and Parkieae. The Acacieae, with the genus *Acacia*—in which the filaments are free or only grown together to form a short ring—are undoubtedly the most primitive of the Mimosoideae, and apparently the plants of the genus *Acacia* are the most primitive of all of the Acacieae. Therefore, Australia shows the greatest number of oldest types among the Mimosoideae.

The subfamily Papilionatae presents much the same evidence. The most primitive tribes of the Papilionatae are those which have free stamens—the Sophoreae and the Podalyrieae. The Sophoreae generally have pinnate leaves, while the Podalyrieae have simple or digitate, rarely pinnate, leaves. Because of their simple leaves, the Podalyrieae may be considered the more primitive tribe. The Podalyrieae number 350 species in Australia, while

all of the other tribes of Papilionatae are far less numerous.

In summary, as far as the Leguminosae are concerned, it can be said that the Mimosoideae and the Papilionatae show the most pronounced development of primitive species in Australia.

Among the tribes of the Labiatae, the Prostanthereae are by far the most numerous in Australia, having 89 species compared with 31 for all of the other tribes. If we study the subfamilies of the Labiatae, as they are considered by Briquet (in Engler and Prantl, 1897), we come to the conclusion that the most primitive species must be those having no gynobasic pistil—the members of the tribes Ajugoideae and Prostantheroideae. When we investigate these two groups we learn that the Prostantheroideae have ovules with endosperm, while the Ajugoideae do not show any endosperm in their seeds—evidence that the Prostantheroideae are the most primitive of the Labiatae. These primitive Prostantheroideae are confined exclusively to Australia.

Among the Myrtaceae we think that the subfamily having dry fruits—the Leptospermoideae—is the most primitive. In Australia there are about 596 of these species with dry fruits, compared with only 41 species of Myrtoideae which bear berries. In Australia, then, the older subfamily has about 14.5 times as many species as does the younger one. The proportion of Leptospermoideae to Myrtoideae in the rest of the world is quite different: there are 678 species of Leptospermoideae and 1,932 species of Myrtoideae, a ratio of 1:2.85.

Among the Rutaceae the most primitive species are placed in the subfamilies which are inclined to apocarpy rather than in the subfamilies with united carpels (e.g., the Flindersioideae, Spathelioideae, Toddalioideae) or in those with bacciform fruits (e.g., the Aurantioideae). The Rutoideae show a tendency to apocarpy, and among their subfamilies several groups have developed: (a)

those with dorsiventral flowers (the American Cusparieae); (b) those without endosperms (the African Diosmeae); (c) those having herbaceous or suffruticose habit (the Ruteae of the northern temperate zone); and (d) those species with doubly digitate leaves (the Dictyolomeae of tropical South America). The remaining tribes of the Rutoideae are the Xanthoxyleae and the Boronieae. The Xanthoxyleae have a tendency to produce unisexual flowers, a characteristic which, for this group, is regarded as a derived feature. The most primitive types of the Rutaceae, then, are probably the Boronieae, and these types are limited to Australia and New Caledonia. In Australia there are about 143 species of the Boronieae and 26 species of the Xanthoxyleae, but only 9 species of the Flindersieae, 7 of the Aurantieae, and 3 of the Toddalieae. These figures, which could readily be supplemented with more evidence, show clearly enough that the primitive Rutaceae appear nowhere as plentifully as they do in Australia.

In considering the Loranthaceae, Engler (1894) mentions the Lorantheae as the first state of development and the Viscoideae as the secondary one. The most primitive of the Lorantheae are non-parasitic trees which have no berries—members of the genera *Nuytsia* and *Gaiadendron*. The species of *Nuytsia*, with dry false fruits, are considered more primitive than the species of *Gaiadendron*, with drupe-like false fruits. The species of *Nuytsia* are found only in western Australia. Of the four species of *Gaiadendron*, three are found in the Andes from Peru to Colombia, and one is found in eastern Australia.

Among the Dilleniaceae, two of the subfamilies, the Actinidioideae and the Saurauioideae, show a derived feature in the fusion of their carpels and further development in that the Actinidioideae and most of the Saurauioideae bear real berries. Neither of these subfamilies is represented in the Australian

flora, the Actinidioideae being found in Japan, China, Manchuria, and the Himalayas, while the Saurauioideae are found in tropical Asia and America. All of the Australian species of the Dilleniaceae belong to the more primitive subfamily, the Dillenioidae. One of the tribes of the Dillenioidae, the Acrotremeae, is found outside of Australia, in India and Ceylon; but this is a less primitive tribe than is the Australian one, showing a number of derived characteristics, such as united carpels, a bushy habit, and pinnatifid leaves. The other tribes of Dillenioidae—the Tetracereae, Hibbertieae, and Dillenieae—which also have representatives in southern Asia and tropical America, are not well enough known at present for a decision concerning the degree of their primitiveness or evolution.

Among the Restionaceae, the Diplantheae have dithecic anthers and the Haplanthereae have monothecic anthers. Naturally, those genera with dithecic anthers are regarded as being the more primitive. They appear only in southwestern Australia; the genus *Anarthria*, with free anthers and a trilobular ovary, is the most primitive of them all. Among the Haplanthereae no differentiation can be made upon phylogenetic characteristics, for here the Australian and the African species share some characteristics. Nevertheless, the most primitive representatives do not appear outside of Australia.

The Centrolepidaceae show quite a similar relationship: among them, too, the species with dithecic anthers are also the more primitive ones. They are represented by the genus *Juncella* in southern Australia and in Tasmania.

The Goodeniaceae, although not completely endemic, have most of their representation in Australia. The most primitive genus in the family is *Calogyne*, which has bifid or trifid pistils. Two species of the genus are found in Australia and the third in south China.



Of the seven tribes of the family Proteaceae, the Persoonieae is the most primitive, as Engler has stated in his *Natürliche Pflanzenfamilien* (III/1: 127). The Persoonieae are found in Australia, Tasmania, New Caledonia, and, to a lesser extent, in New Zealand. One species of *Brabeium* appears at the Cape of Good Hope, but has developed farther than its relatives in Australia, as is proved by its floral axis which shows a cyathiform excrescence at the base. In any event, the most primitive representatives of the Proteaceae are almost completely limited to Australia.

In the Santalaceae, the members of the tribe Antholobaeae, with their superior ovary, are considered primitive. The genus *Antholobus* is native to Australia. A closely related genus, *Exocarpus*, is found in Australia, Norfolk Island, the Malaysian islands, India, Madagascar, and Hawaii, although most of its species are native to Australia. The genus *Champereia* is found in Malacca and the Malaysian archipelago. It can be concluded, therefore, that the Santalaceae are of Australian-Malaysian—that is to say, of post-Gondwanesian—origin.

The most primitive Apocynaceae are those in which the stamens are not tightly connected with their stigma heads. These are the Plumierioideae, especially a subgroup of them, the Pleiocarpeae, which have apocarpic ovaries, pistils split at the base, and more than two carpels. Among them are two genera with the primitive arrangement of alternate leaves: *Notonerium* Benth., an ericoid bush growing in southern Australia, and *Lepimia* Decne., a tall tree found in Tahiti. The most primitive species of the Apocynaceae, therefore, are Australian-Pacific in their origin.

It might be noted in passing that this same conclusion cannot be drawn for the Asclepiadaceae. Here the Periploceae are the most primitive forms, judging by their tetrad pollen, the translators of which have no reticula; and of these primitive Periploceae,

the most primitive are those which possess no corona, as, for example, the *Gymnolaima* of Kilimanjaro, Africa, the *Phyllanthera* of Java, and the *Pentamera* of Sumatra. The Asclepiadaceae are generally more highly evolved than are the Apocynaceae, but they do not originate in Australia.

Let us now go on to consider a rather complicated group, the Cyperaceae. Here the species of Scirpoideae, with their hermaphroditic flowers, are more primitive than are the Caricoideae, the flowers of which are rarely hermaphroditic. The nature of the axes in the inflorescences of the Caricoideae also proves to be a derived feature. Among the Scirpoideae there is a tribe, the Hypolytreae, whose members have bracted flowers; and the transverse arrangement of these bracts (as occurs among the Hypolytrinae) might be a more primitive characteristic than is the possession of one or two median bracts (as occurs among the Lipocarphinae). Among the Hypolytrinae the genus *Hypolytrum*, whose species show free bracts, is most primitive. A species of *Hypolytrum*, *H. latifolium* L. C. Rich., is found in Queensland, but it is also found in south Asia, Africa, America, and Polynesia. Two species of *Lipocarpha* also have an extensive range. The genus *Hypolytrum* has its representatives in the tropical and subtropical ranges of both hemispheres. All of this evidence would seem to show that the oldest living types of Cyperaceae—which is considered a rather "modern" family—have their native habitat in the tropics, but by no means in Australia.

In contrast to this, the oldest genus of the Scirpoideae-Cyperinae, the genus *Carpha* R. Br.—without disk, but with setaceous involucre, six setae, and a three-cleft pistil—is represented by one species from Australia and New Zealand and by another in extra-tropical Andean South America.

In the large subfamily of the Caricoideae, the Rhynchosporeae are the most primitive, inasmuch as, in most cases, they have three

anthers and an involucre. If we except the genus *Oreobolus*—which is somewhat in a special position because of its circum-Pacific distribution and its single, terminal, one-flowered false spikelets (Suessenguth, 1942)—we note that genera with alternate or very slightly distichous bracteal scales are more primitive than are those with distichous scales. Among these genera the most primitive are those which have three style branches and an involucre; of these genera three are especially worthy of consideration here:

*Lepidosperma*, with nine-tenths of its species found in Australia, two in New Zealand, and two in tropical east Asia

*Tricostularia*, with five-sevenths of its species found in Australia, one in Borneo, and one in Ceylon

*Decalepis*, with one species found at the Cape of Good Hope in South Africa.

From this evidence we see that—again if we except the genus *Oreobolus*, which is of old-Pacific origin and which is difficult to classify—most of the oldest types of the Caricoideae are to be found in Australia, while the most primitive species of the whole family of the Cyperaceae are found in the tropics.

In order to complete the picture we should consider some of the families, the origin of which cannot be traced to Australia.

Of the Anacardiaceae the most primitive genus is *Buchanania*, native to tropical Asia, especially to the Malaysian territory, and to northern Australia. The most primitive species of *Buchanania* have four to six free carpels, of which one is fertile.

The Compositae are impossible to trace to their origin, or to differentiate into their most primitive groups, even if we exclude from consideration the tribes which are obviously derived, like the Liguliflorae and the Mutisieae.

The family Cucurbitaceae is divided into the Fevilleae and the Fevillinae. The Fevilleae are the more primitive, having five free anthers and loculamenta which are not grown

together to form a circular ring (except for the slightly more developed Gomphogyninae and the Zanoninae, which have unilocular ovaries). The Fevillinae have trilocular ovaries, and, of course, are more highly evolved than are the Fevilleae. All of these plants are native to tropical America, Brazil, and the West Indies.

Among the Orchidaceae, the more primitive species (the Diandrae-Apostasiinae) are not found in Australia. Species of the genus *Neuwiedia*, which have three fertile stamens, appear in Malacca and the Malaysian archipelago; those of the genus *Apostasia*, which have two fertile stamens, appear in the East Indies, the Malaysian archipelago, and tropical Australia. From this it is evident that the oldest types of the whole family belong to the tropics and are found today in territories lying north of Australia.

The distribution of the Piperaceae (as, indeed, of many another smaller family), leads us to expect a tropical origin for them.

Of the Rubiaceae, the more primitive subfamily is that of the Cinchonoideae, whose species have many seeds in each locule of the ovary. Among the Cinchonoideae, the Cinchoninae are more primitive because of their dry fruits. More highly developed groups, like the Condamineae and, to some extent, the Rondeletieae, have radiate flowers which are single or in panicles (but not in clusters), apterous seeds, whole or bipartite stipules, and the habit of trees or shrubs. The Rondeletieae, however, show imbricated or contorted veneration of the corolla, and the contorted veneration, at least, is a derived feature. Among the Condamineae the most primitive species are those in which the sepals are of equal size and in which the petals are simply valvate and not reduplicatively valvate.

The simply valvate species are placed in the genera *Condaminea* (found in Andean South America), *Chimarrhis* (found in Andean South America and in the Antilles),



*Rustia* (from Central America to Brazil), and *Tresanthera* (in Venezuela and in the West Indies). None of these genera even so much as appears in Australia. The reduplicatively valvate species of the Condamineae are placed in the genera *Portlandia* (found in the West Indies and in Mexico), *Isidorea* (in Haiti and Cuba), *Bikkia* (from the Pacific islands, New Caledonia, and Malacca), and *Morrierina* (found in New Caledonia).

Of the Rondeletieae, the simpler species, in which there is no contorted veneration of the corolla and in which the petals are not evolved into showy organs, are placed in the genera *Rhachicallis* (found in the Antilles), *Bathysa* (found in Brazil), and *Rondeletia* (found in the Antilles, Central America, and the northern parts of South America).

All of this evidence proves that the Rubiaceae did not originate in Australia, but primarily in the tropical regions of Central and South America and in the West Indies, and only in lesser part in the regions of New Caledonia and the Moluccas.

The most primitive species of the Valerianaceae appear on the Asiatic mainland: Species of *Nardostachys*, with four stamens and the clearly five-parted edge of the calyx, are found in the central Himalayas; species of *Patrinia*, with four stamens, extend westward from Japan through central Asia to the Ural mountains and northward into Arctic territory.

Now, in recapitulation, let us list all the larger systematic groups of the angiosperms, the most primitive types of which are found in Australia: Labiatae, Mimosoideae, Papilionatae, Myrtaceae (sub-family Leptospermioideae), Rutaceae, Santalaceae, Apocynaceae, Goodeniaceae, Proteaceae, Restionaceae, Centrolepidaceae, Loranthaceae, Dilleniaceae, Cyperaceae (subfamily Caricoideae). This summary and all of the evidence leading up to it are of great importance for the proper evaluation of many of the problems and questions in the science of plant geography.

Most of these groups cannot be considered primitive in the general phylogenetic sense—as, for example, these nine of the 14 families: the Labiatae, Papilionatae, Mimosoideae, Restionaceae, Centrolepidaceae, Apocynaceae, Myrtaceae, Goodeniaceae, and the subfamily Caricoideae of the family Cyperaceae. This would mean that the angiosperms which have developed in Australia since the Upper Cretaceous period cannot be traced back to the very earliest groups of angiosperms. These ancient groups must have developed in much earlier times than the Upper Cretaceous. It is not likely that the nine families have spread from Australia to other parts of the world after Australia's geographic isolation began and that the original primitive species have been conserved in Australia ever since that time. On the contrary, it is much more probable that the primitive ancestral types also existed in other parts of the world even before the Upper Cretaceous period and that they have died out there since that time, just as most of the Marsupialia and the Monotremata have died out in parts of the world outside of Australia. Finally, it should be remembered that it is also possible that the Australian angiosperms of today might have had ancestors originating in other continents before the beginning of Australia's geographic isolation.

It is likely, too, that many of the families of the Australian plants have migrated into Australia in times later than the Upper Cretaceous period, especially those families found now in northern, tropical Queensland.

All of this would mean that parent types of most of the derived families of Angiospermae were already in existence before the Upper Cretaceous period, and that the development of the main branches of the Angiospermae took place in even earlier times. Fossil discoveries lead us to suppose that a strong and rapid development of angiosperms has taken place since the Upper Cretaceous period. Investigations of the

Australian flora do not confirm this impression, however. Rather, they support the supposition that, in most of its essentials, the development of flowering plants goes back to even earlier times—to the period of Lower Cretaceous formations, possibly even as far back as the Jurassic period. Unfortunately there are not many fossil evidences of angiosperms preserved from Jurassic times, and very few of these can be identified with certainty. When the Cenozoic era began, the chief development of the angiosperms must already have been finished. Particularly primitive types might have been preserved until then, of course, but there is no definite fossil evidence as yet of this possibility.<sup>2</sup>

#### COMPARISON OF AUSTRALIA WITH NEW ZEALAND

In this connection it might be significant to draw a parallel by investigating a land area near Australia and which has been isolated from other continents for even a longer time than Australia. Such a territory is New Zealand. No fossil mammals were found there, while, as we know, primitive mammals had entered Australia from southern Asia. In the event that some of these mammals originated in Australia itself—a rather untenable supposition—they must have wandered out of Australia over land bridges toward the north, eventually to reach Europe and North America. In New Zealand, on the other hand, only a small rat has been found to represent the mammals, and this rat was probably imported by man

in very recent times. The islands of New Zealand have never been connected with land areas inhabited by mammals, and until now no fossil relics of mammals have been found there; it is very unlikely, therefore, that mammals did live in New Zealand at one time but have died out there since.

Now, if New Zealand has never been connected with land areas populated by mammals, where did its flora come from? And does this flora show still more primitive features than does that of Australia?

Diels (1897) has entered into a full discussion of these questions in his work on the *Vegetationsbiologie von Neuseeland*. He assumes that New Zealand has not been submerged since the middle of the Mesozoic era. According to Hutton (cited by Diels, 1897), New Zealand was connected with an Antarctic continent which existed during the Lower Cretaceous period, toward the end of the Mesozoic era. Diels thinks it is probable that, even during the later Triassic period in early Mesozoic time, the Austral circumpolar lands were closely related to each other, so that there was a genetical connection among the mountain floras of Tasmania, southern Australia, the southernmost part of South America, and an Antarctic continent which probably was more temperate in its climate in those early times than it is now. This interrelationship of floras would find its parallel in the Arctic, Alpine, and Altaic floras of the northern hemisphere.

In his paper, Diels cites evidence to support this supposition of the connection of the Antarctic and Austral land masses. In those times the Antarctic continent must have been much larger than it is today, free from ice in its northern parts, and certainly warmer during the Triassic period. In addition to Diel's evidence, we can find further testimony in comparative zoology and in plant geography. Fossil relics of marsupial groups now limited to Australia—species of the

<sup>2</sup>Erdtman in 1948 published reports in *Grana Palynologica*, that pollen had been found in the black lias formations of southern Sweden. The pollen appears similar to that of *Eucommia* species (*Eucommia* is a genus in China, closely related to the Ulmaceae) and it is not likely to have been derived from Gymnospermae. Inasmuch as the black lias of Sweden is a Lower Jurassic formation, these pollen finds may offer some evidence of the early development of the angiosperms.



Abderitidae, and of the Sparassodontidae, which are related to the Dasyuridae—have been discovered in Eocene deposits in Patagonia; and Zittel (1895) concluded that "it is an undeniable paleontologic fact that in those times both regions were in mutual exchange or at least drew from the same sources." But only the western isle of the former Australian archipelago (the West Australia of today) participated in this exchange. The eastern islands, particularly New Zealand, did not—because they were not connected either with western Australia or with Patagonia. The most primitive species of marsupials—species of *Myrmecobius* and *Peragalea*—are endemic to West Australia, and it is a very significant fact that there is no fossil evidence to prove that marsupials existed in eastern Australia at any time before the late Cenozoic era, that is to say, before the central Australian sea had retreated (Zittel, 1895: 294). All this is evidence that there must have been connecting land links between Patagonia and western Australia.

We find a very interesting parallel in the distribution of two sections of the genus *Discaria* of the family Rhamnaceae. The section *Notophaena* (Miers) Suessenguth, in its present range, connects Chile and New Zealand. The section *Eudiscaria* Stapf appears in the Argentine countries (that is, in the countries east of Chile), and in Tasmania, Victoria, and New South Wales. This distribution can be explained only by assuming two land bridges leading through an Antarctic continent—one connecting Chile and New Zealand, in a strip slightly arched towards the south; another, farther south than the first, leading from eastern Patagonia through the Antarctic continent to Tasmania and southeast Australia.

It is my opinion that all sketches of these hypothetical land bridges which have been published are not quite correct, for it is impossible—for phylogenetical as well as pale-

ographical reasons—that the connection from Chile to east Australia could have been formed in a straight line. On the contrary, this line passed farther south through an Antarctic continent, which at that time was overgrown with plants.

According to Hutton and Wallace (cited by Diels, 1897), a Melanesian continent connecting New Caledonia, Lord Howe Island, Norfolk Island, and New Zealand, and reaching as far north as the present north Queensland, might well have existed in the Eocene epoch. There was no connection, however, between this continent and western Australia. In Miocene times west Australia and east Australia were connected, but the west Australian species never reached the tropics, and, therefore, did not get to New Zealand.

From these few considerations we learn that the situation in New Zealand is quite different from that in Australia. New Zealand was closely related to the Antarctic continent and to a Melanesian continent, but we cannot expect to find there the primitive species of the Australian continent. The different character of the flora of New Zealand is proof of this expectation. In their *Manual of the New Zealand Flora*, Cheeseman and Oliver (1925) list 1,591 species of vascular plants, with 1,415 phanerogams and 156 vascular cryptogams, among all of which are 1,143 endemic species—72.8 per cent—and 24 endemic genera. While Mueller's catalogue counts 592 species of Proteaceae in Australia, only two can be listed for New Zealand. The large Australian genera of *Eucalyptus* and *Acacia* are completely missing in New Zealand. The floristic connection of New Zealand with Australia is formed by certain of the Myrtaceae (the genus *Metrosideros*) and by the family Epacridaceae. According to Grisebach (1872: II, 633) these are the New Zealand families or groups which are represented by the most species:

PLANT GROUP	NUMBER OF SPECIES	PERCENTAGE OF VASCULAR PLANTS REPRESENTED BY GROUP
Compositae . . . . .	221	14.1
Ferns . . . . .	138	8.8
Cyperaceae . . . . .	119	7.6
Scrophulariaceae . . . . .	113	7.2
Gramineae . . . . .	113	7.2
Umbelliferae . . . . .	62	3.9
Orchidaceae . . . . .	57	3.6
Ranunculaceae . . . . .	50	3.2
Rubiaceae . . . . .	47	3.0
Epacridaceae . . . . .	31	2.0
Onagraceae . . . . .	31	2.0
Leguminosae . . . . .	26	1.7
Juncaceae . . . . .	25	1.6
Boraginaceae . . . . .	25	1.6

The differences between the figures for New Zealand and those for Australia are very striking: Leguminosae, ranking first in Australia, is not among even the first 10 of the families of New Zealand, and neither is Myrtaceae (in second place in Australia), Proteaceae (in third place), or Euphorbiaceae (in eighth place). The Compositae, however, have achieved first place in the New Zealand flora (they are in fourth place in Australia), and—the ferns being left out of consideration—the Scrophulariaceae, the Umbelliferae, the Rubiaceae, and the Ranunculaceae have entered into the list of families with the most species. The Labiatae, in contrast, are not to be found at all in New Zealand; they did not reach these islands from Malaysia and Australia.

Of the 1,591 plant species found in New Zealand, 428 species are not endemic. Among these, 366 are related to the Australian flora, and 108 are related to that of South America.

The genera with the greatest number of species in New Zealand are these: *Veronica*, 84 species; *Carex*, 54; *Celmisia*, 43; *Coprosma*, 40; *Ranunculus*, 38; *Olearia*, 35; *Senecio*, 30; *Epilobium*, 28; *Poa*, 25; *Myosotis*, 23; and *Hymenophyllum*, 20.

It cannot be said, however, that New Zealand's flora is more primitive or has more primitive species than does the flora of Australia, even though its isolation from Malay-

sia and New Guinea apparently occurred earlier than did that of Australia. The great number of endemics in New Zealand's flora, then, can be attributed not to the conservation of primitive species, but rather to the formation of new ones.

Because of its temporary connection with Australia, Melanesia, and the Antarctic continent, New Zealand cannot give us any assistance in solving the problem of the origin of the larger and older Australian flora, so important in any estimation of the age of the angiosperms. The geologic and biologic records left on New Zealand are quite different from those of Australia, and they can not be traced very far back into geologic time.

#### ORIGIN OF NEW TYPES IN AUSTRALIA

How, then, can we explain the appearance of new types in Australia? Perhaps the following supposition may be the simplest one.

Let us assume that during the Upper Cretaceous period, or possibly during the Middle Cretaceous period, but in any case a short time before Australia's geographic isolation began, there existed the plant types A, B, C, D . . . in *Malaysia as well as in Australia*. Since that time, the Malaysian types have evolved into types A<sup>1</sup>, B<sup>1</sup>, C<sup>1</sup>, D<sup>1</sup> . . . that is, into new and different species or genera. The Australian types, however, have developed into types A<sup>2</sup>, B<sup>2</sup>, C<sup>2</sup>, D<sup>2</sup> . . . into different species or genera from both their parent types, A, B, C, D . . . and the collateral types A<sup>1</sup>, B<sup>1</sup>, C<sup>1</sup>, D<sup>1</sup> . . . developing in Malaysia. It is conceivable that the endemic plants in Australia have evolved in this manner.

Of course it is also possible that this development of endemics could have taken place in later times, without it being necessary for us to conclude that all species of the parent series A, B, C, D . . . must have been distributed throughout Malaysia and



Australia during the Upper Cretaceous period. Many of them may have migrated to Australia in later times, after the separation, and may have evolved there into types  $A^2$ ,  $B^2$ ,  $C^2$ ,  $D^2$ . . . . But if this is true of some plants, it is not likely to be true of the Leguminosae: It is probable that the primitive species of the Mimosoideae, the Papilionateae, and of some of the *other* families listed above (p. 295) immigrated into Australia a long time ago and have survived there unchanged, remaining generally identical with their ancestors of the Upper Cretaceous period, wherever these ancestors may have grown.

For some of the other plant groups, it is possible that their species  $A^2$ ,  $B^2$ ,  $C^2$ ,  $D^2$ . . . may have risen in different epochs.  $A^1$ ,  $B^1$ ,  $C^1$ ,  $D^1$ . . . in Malaysia, and  $A^2$ ,  $B^2$ ,  $C^2$ ,  $D^2$ . . . in Australia, continued to live, while their common ancestors A, B, C, D. . . died out in both territories. Or, if we assume that  $A^1 = A$ ,  $B^1 = B$ ,  $C^1 = C$ , and so on, or if we take  $A^2 = A$ ,  $B^2 = B$ ,  $C^2 = C$ , and so on, we might deal, then, with only two lines of development instead of three, and only one of them need have changed—either the one in Australia, since the beginning of its isolation, or the line in Malaysia, since Australia's separation. In other words, the local ancestors of the line A, B, C, D. . . might have died out in one territory and might have been preserved in the other for a very long time. Yet this is not very probable a chance inasmuch as most species of living things—except for the mussels—generally have not been conserved unchanged over long periods of geologic time.

In my opinion this line of approach is the most natural way of explaining the problem. It does not relegate the appearance of all the endemic families of the Australian angiosperms to the apocryphal darkness of antiquity, and yet it does help us to understand the rise of the many endemics in Australia. If we do not insist that all of

these developments took place at almost the same time (in the Upper Cretaceous period) and if we agree that the possibility of subsequent immigrations into Australia must also be taken into account, then we would do well to remember that in their manner of distribution angiosperms and mammals differ markedly in at least this major point: Flowering plants are much more able to cross the sea—if only by means of driftwood—than are mammals. This would seem to be an assertion that could hardly be contested. And yet it is a strange fact that greater numbers of primitive plant types have not been preserved. They became extinct, while the primitive types of animals—the Marsupialia and Monotremata—continued to live. These animals link the mammals with the reptiles, but even at the present time no plants are known in Australia which link the angiosperms with the gymnosperms. The botanical systematist will regret this fact, if only because such proof of primitiveness would be a much more scientific, and therefore a more reliable, basis for the taxonomic system.

My impression of the rise of Australian endemics has been described with reference to its relationship to Malaysia, both because the endemics of this area are more closely related to those of Australia and because of Australia's former connection with New Guinea (see Behrmann, 1937). Perhaps these conclusions will seem quite natural to most readers; nevertheless, I think it would be useful to develop further conclusions based on certain concrete suppositions.

As has been known for a long time, most of the species of the plant families characteristic of Australia grow in the southwestern maritime areas (Hooker, 1860). Fewer species are found toward the north. According to his catalogue, Hooker counted 3,600 species in the southwestern territory, known in his day as Swan River and King George Sound, but only 3,000 from the eastern area,

and only 2,200 from tropical Australia, where the endemic species are fewest in number. Now what is the reason for this distribution? Is it because Malaysia has exerted less of an influence upon these southwestern districts because they are so distant, and because they are separated from the interior—and therefore from the northern shores and Malaysia—by vast deserts? Is this pronounced isolation the reason why more endemic species have developed and have been preserved in the southern periphery of Australia than in its other parts? Or is there a more general rule, as yet unexplained, that endemics are developed more generously in southern lands?

If we compare South Africa with Australia, we can count an enormous number of endemics in Cape Colony; and if we compare the most southern parts of South America—Patagonia and Chile—with Australia, we can find there, too, a great number of endemic species—1,200 of 1,600 species, according to Grisebach's early evaluation in his *Die Vegetation der Erde* (1872: II, 498).

It is not possible to indicate a preponderance of endemisms in the most southern part of India, at least on the basis of the figures reported by Hooker and Thomson in their *Introduction to the Flora Indica* (1855). Newer statistics concerning Indian endemisms apparently are not yet published.

In Europe, however, the majority of endemics is found in the southern areas, particularly in the Balkans and in Crete (Turrill, 1929). In this connection, Newbigin (1936) has made these statements about mammals: "It has been made abundantly clear that the great migratory movements have been from the wide land masses of the northern hemisphere towards the narrower and discontinuous southern ones, and that extinction of early stocks has been most marked in the Holarctic region, while the survival of members of these is especially characteristic of some of the southern lands. . . . The past and present distribution of the higher plants con-

firms the conclusions derived from the study of mammals. Sometimes the correspondence is curiously exact." Unfortunately, Newbigin does not give his proofs of these lapidary sentences, particularly for the plants. Let us, therefore, find our own proofs in some examples from the pertinent literature.

A good many of the flowering plants, as, for example, the families of the Papaveraceae and the Geraniaceae, have migrated along the ridges of the Andes, from both North America and Central America, far into South America (Vester, 1940: 162, fig. 78). The genus *Ribes*, which also migrated in this manner, has been cited for this fact by Newbigin (1936). The same evidence of migration appears to be provided for some of the Primulaceae, with *Primula farinosa* in the Holarctic region and in Andean Patagonia (Vester, 1940: 154, fig. 40); for the Betulaceae (*ibid.*, 163, fig. 80); for the Empetraceae (*ibid.*, 163, fig. 81); for the Orobanchaceae (*ibid.*, 164, fig. 86); and for the Juglandaceae (*ibid.*, 176, fig. 153).

Fossil discoveries give further evidence that, to a great extent, some of the plant groups were forced out of northern areas into southern not only by diluvial glaciers, which, coming from the north, destroyed the Cenozoic flora of central Europe and of central North America, but also by hitherto unknown factors which were effective much farther southward. The Magnoliaceae, for instance, at one time must have grown over vast parts of the Holarctic region, but today they are limited to South and Central America, eastern and southeastern North America, the West Indies, southwestern Asia, Malaysia, eastern Australia, and New Zealand (Vester, 1940: 188, fig. 262). The Juglandaceae, too, have disappeared from large areas of northwestern North America, from Europe (except for the Balkans), and from central Asia (except for the Caucasus), while in the more southern regions they continue to survive. Further examples are to be found in the fam-



ily Ebenaceae, according to Fernald (*in* Vester, 1940: 174), and in the tribe Cycadeae and the genera *Podocarpus* and *Araucaria*, according to Studt (1926).

It is doubtful whether any instances can be found to prove a considerable migration of a plant flora in the opposite direction, that is, from south to north. It is true, of course, that a number of plants, reported by Suesse nguth (1942), have worked their way northward from the South American Andes, reaching as far north as Costa Rica and Mexico. However, these migrations have taken place only since the Miocene elevation of the Cordilleras in Central America, and they are rather insignificant compared with the major southward migrations.

There is evidence, however, that northeastern Africa has been reached from a northeastern direction by species of plants from India and western Asia.

Although it might be expected that the Mediterranean floral elements might have arrived in central Europe from the south, following the retreating glaciers as they withdrew to the north, I do not think this argument is tenable, inasmuch as it is quite possible that representatives of the Mediterranean flora might have found refuges in the climatically favorable parts of central Europe during the glacial advances. It is much more likely that the North American plants of Cenozoic time were forced southward by the glaciers, and then, after the glaciers had retreated, were permitted to return north, to recover vast territories of their former areas of distribution. Nonetheless, these instances of northward migration are abundantly surpassed by the notable removal to the south of plants in Australia, the Andes, Patagonia, Cape Colony, and the Balkans, in all of which real displacements to the south have been demonstrated. During the cold periods of the glacial advances, all of the hydro-megatherms and megatherms should have been concentrated towards the tropics from the Arctic

and Antarctic regions, and it is not to be denied that a large part of the "small belt-like areas" of many families in the whole tropic range may thus have been established in their present ranges (Vester, 1940: 166 *et seq.*, figs. 93–113). Nevertheless, it seems as if in Australia, the Andes, Africa, and Europe other factors had contributed to force a great number of species of plants from the north to the south, and in those areas in the southern hemisphere this displacement carried the plants even farther south than the Tropic of Capricorn.

This phenomenon of displacement from north to south does not need the supposition of some mystical power to explain it. In Africa, for example, a northward counter-displacement of the ancient flora of the northern and middle part of the continent could not happen because it was blocked in that direction by the broad Tethys sea of the early Tertiary period (Eocene time, and so on) or by the deserts that are its relics. Australia, to give another example, in post-Tertiary time could not receive plants from any direction but from the north, because it was only there that Australia was connected, if only temporarily, by land bridges with large masses of land, while in the south the Antarctic continent at a later period was too cold and too far distant to permit of plant migration. In the Andes plant distribution is not as easily explained. In the Balkans the lowering of temperatures in the north by the glaciers may have played a part in the southward displacement of the plant life, so that numerous types of plants died out in the north which continued to live in the south. It would be of great interest to investigate the degree of displacement in still other parts of the world.

Many other objections might be raised to dispute this claim of the southward displacement of plants. The major point of dispute is whether or not this southward displacement of certain systematic groups—such as,

for example, the Magnoliaceae, which are said to be analagous in this respect to many animal groups—can be attributed only to the lowering of temperatures in the northern regions during the time of glaciation.

#### CONCLUSION

These investigations have offered statistical evidence that the phylogenetically older types of about 10 large taxonomic groups of the higher plants are found, either exclusively or in their great majority, in Australia. By analyzing the floras of the lands near Australia today, and by drawing analogies from the floras of the southern parts of all of the other continents, it can be concluded that the ancestors of the Australian plants must have existed in Australia during the times of the Upper Cretaceous period. This can be the only conclusion because it would be impossible for the Australian flora to form one vast atavism, if only because atavisms are rare, when they are encountered at all, and usually play no part in the formation of species.

It should be stressed that in order to reach this conclusion no contrived assumptions were made regarding the primitiveness of the characteristics of the Australian plants: Concepts and judgments of primitiveness were based entirely upon the well-established criteria of the older taxonomic systems (the *Natürliche Pflanzenfamilien* of Engler and Prantl, for example) and upon the general discussions of phylogenetically important characteristics given by Wettstein in his handbook of systematic botany (1935) and by myself (Suessenguth, 1938), without dependence upon rules or criteria established particularly for the Australian flora. The special questions of the phylogenetic age of Australian families put in this paper, and the answers proposed to them, have not been presented before, to my knowledge.

The data obtained in these investigations would suggest that natural immigrations of plants into Australia, after the beginning of

its isolation from Malaysia, were not very likely—or at least were not very plentiful—the enormous degree of endemism which Australia now exhibits being evidence against any considerable change in later times.

It cannot be established with certainty whether or not the plants of the primitive genera of the 10 major Australian families are not only endemic by preservation but are also plants which have originated in Australia and which have existed there since their beginning to become the ancestors from which the families have spread throughout the world. In the majority of cases I do not think it likely that these plants have been disseminated from an Australian center inasmuch as paleontological evidence concerning animals shows that many animals which at one time were widely distributed have been preserved alive in Australia while they have become extinct in other regions. Obviously, what has happened to animals could also have happened to plants.

We can conclude, however, from the indirect evidence presented by the Australian flora that the development of primitive families of the angiosperms must have taken place during the Middle and Lower Cretaceous period or, possibly even earlier, during the Jurassic period. But this conclusion, while it is supported by the endemic nature of the Australian flora—which, of course, was isolated when the connection of Australia with Malaysia was ended in the Upper Cretaceous period—has yet to be confirmed by the discovery of fossil evidences of angiosperms in formations of those Middle Mesozoic times.

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# The Osteology and Relationships of the Echelid Eel, *Kaupichthys diodontus*<sup>1</sup>

WILLIAM A. GOSLINE<sup>2</sup>

## INTRODUCTION

THE MAIN FUNCTIONS of the present paper are to demonstrate that two very different families of eels have hitherto been included under the "Echelidae" and to allocate these families to their proper positions in the order Anguilliformes (or Apodes). In order to establish these points, the osteology of *Kaupichthys diodontus* Schultz is dealt with in some detail.

On September 7, 1949, an unripe female of this species, 155 mm. long, was taken by Strasburg, Welsh, and the author in a poison station in shallow water off the aquarium at Waikiki, Oahu, Territory of Hawaii. The species (and genus) was originally described by Schultz (1943: 50, pl. 6 and text fig. 5i) from Tau and Rose Islands in the Samoan group. It is hitherto unrecorded from Hawaii. The specimen at hand differs from Schultz's description (and from a Bikini specimen dealt with below) as follows: the teeth are blunter than indicated in his diagnosis and figure (5i); the two rows of vomerine teeth are not so widely separated, nor do they extend farther posteriorly than the maxillary rows; and finally, the maxillary teeth are quite distinctly set apart from the premaxillary and vomerine groups. Whether the Hawaiian form merits specific or subspecific distinction, or whether the above-mentioned differences are merely individual or size variations, I do not have sufficient material to decide.

In identifying the Waikiki specimen I became doubtful as to its relationship with the other Hawaiian genus—*Muraenichthys*—which has always been placed in the same family with it (Schultz, 1943: 49; Schultz and Woods, 1949: 170). A specimen of *Kaupichthys diodontus* from Bikini, one of the duplicates very kindly sent me by Dr. Schultz, permitted an osteological investigation of that species. From this examination it is very apparent that *Kaupichthys* and *Muraenichthys* do not belong in the same family; in fact they belong on opposite sides of the major division of the eels as classified by Regan (1912) and Trewavas (1932). An account of the osteology of *Kaupichthys*, based on the 100 mm. specimen from Bikini, follows. The specimen was stained in alizarin and the head dissected; the remainder of the specimen was cleared in potassium hydroxide.

## OSTEOLOGY

The lateral line canals of the body and head are enclosed in a series of small bony ossicles except where they penetrate the skull bones. That of the body gives rise to only two pores leading to the exterior; these are both forward of the pectoral (Fig. 1). In the head region the sensory canal system is of rather normal eel pattern (Trewavas, 1932, pl. 4b and text fig. 3A), though the number of pores leading to the surface of the head is somewhat reduced. A longitudinal canal (ll) connects the lateral line of the body with that of the head system. As is usual in eels, a transverse canal (tc) run-

<sup>1</sup>Contribution No. 3, Hawaii Marine Laboratory.

<sup>2</sup>Department of Zoology, University of Hawaii.  
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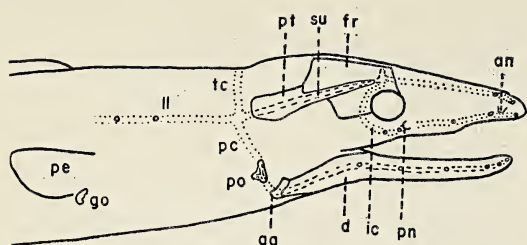


FIG. 1. Outline of head region of *Kaupichthys diodontus* indicating the course of the lateral line canals. Areas in which the canals pass through flesh are shown as dotted lines; areas in which canals pass through bone are shown in dashed lines with the outlines of the bones drawn in. Pores opening to the exterior from the canal system are shown as circles. aa, Articular-angular; an, anterior nostril; d, dentary; fr, frontal; go, gill opening; ic, infraorbital canal; ll, lateral line; pc, preopercular canal; pe, pectoral fin; pn, posterior nostril; po, preopercle; pt, pterotic; su, supraorbital canal; tc, transverse postcranial canal.

ning up and across the nape just behind the skull connects the longitudinal canals of the two sides of the body; it gives rise to a series of pit organs externally but to no pores. The preopercular canal (pc) exits ventrally from the longitudinal canal opposite the junction of the latter with the one crossing the nape and proceeds anteroventrally through the preopercle and into the articular-angular and dentary in a normal manner. The longitudinal canal itself passes forward into the head as the supraorbital canal (su), which runs the entire length of the pterotic and through a short section of the frontal; from here it passes forward in a tube—all that is left of the nasal—to the tip of the snout. In addition, a short branch runs mesially in the frontal, but does not meet its fellow from the other side, nor does it give rise to a pore to the exterior. The infraorbital canal (ic) emerges from the supraorbital system in the frontal, runs laterally and then downward behind the eye and finally forward in the upper lip to the tip of the snout; in the lip it runs mesial to the posterior nostril and below the anterior nostril. The pores open-

ing to the exterior from the lateral line system are shown in Figure 1.

The suspensorium of *Kaupichthys* (Fig. 2) is vertically suspended, i.e., the articulation between the quadrate (q) and the articular-angular (aa) lies but slightly behind the center of the hyomandibular (h). The palatopterygoid (pp) is laminar and well developed for eels, but appears to be unattached, except by a ligament, either before or behind. The maxillary (m) articulates with the combined premaxillary, ethmoid, and vomer (ev) near the tip of the snout. The opercular apparatus is reduced. The preopercle (po), which remains chiefly as a tube for the lateral line canal, overlies the broadly wedge-shaped interopercle (io). The subopercle (sr) completely encircles the opercle (op) below. The top half of the normal fish opercle is gone, only the lower half remaining.

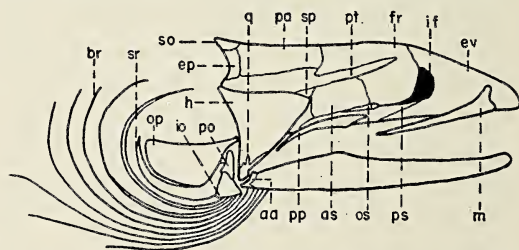


FIG. 2. Head skeleton with suspensorium, jaws, opercular bones, and branchiostegal rays. Teeth are omitted, and all the branchiostegal rays are not shown: as, Alisphenoid; br, branchiostegal ray; ep, epiotic; ev, premaxillary-ethmo-vomer; fr, frontal; h, hyomandibular; if, interorbital foramen; io, interopercle; m, maxillary; op, opercle; os, orbitosphenoid; pa, parietal; po, preopercle; pp, palatopterygoid; ps, parasphenoid; pt, pterotic; q, quadrate; so, supraoccipital; sp, sphenotic; sr, subopercle.

In the cranium (Fig. 3a-d) the premaxillaries are ankylosed to the ethmo-vomer. The orbitosphenoid (or) is a long, slender bone wedged between the parasphenoid (ps) below and the alisphenoid (al) and frontal above. The enlarged otic bulla (ob) is composed ventrally of the basioccipital (bo) and the prootic (pr); it contains a large sagitta



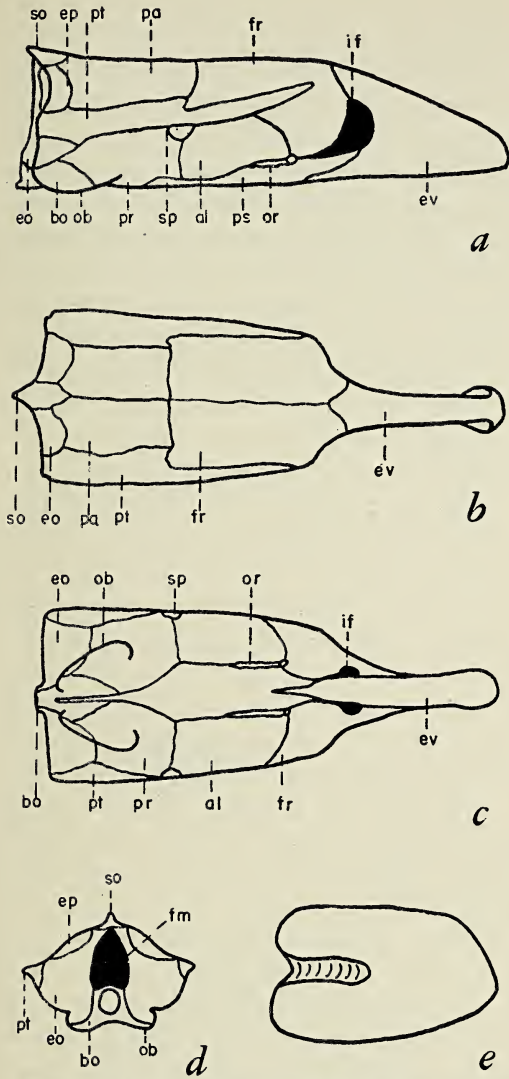


FIG. 3. *a*, Cranium from the side; *b*, from above; *c*, from below (teeth omitted); *d*, from behind; *e*, sagitta. al, Alisphenoid; bo, basioccipital; eo, exoccipital; ep, epiotic; ev, premaxillary-ethmovermer; fm, foramen magnum; fr, frontal; if, interorbital foramen; ob, otic bulla; or, orbitosphenoid; pa, parietal; pr, prootic; ps, parasphenoid; pt, pterotic; so, supraoccipital; sp, sphenotic.

(see Fig. 3*e* this paper and Frost, 1926: 99). On the dorsal surface of the skull the frontals are completely divided by suture; the parietals (*pa*) are rather large for eels; the pterotics are elongate. On the posterior face of the skull the foramen magnum (*fm*) is large

and the socket for the articulation of the vertebral column relatively small for eels. The first vertebra is not fused to the skull.

The branchial apparatus (Figs. 4 and 5) is of normal eel type, without specialized features. There are 15 branchiostegal rays (*br*) on each side; those of the two sides of the head do not overlap on the midventral line and rather closely encircle the opercular bones behind. The upper pharyngeals (*up*) articulate with the upper ends of the third and fourth branchial arches. The fourth arch closely adjoins the lower pharyngeals (*lp*) below. Both upper and lower pharyngeals

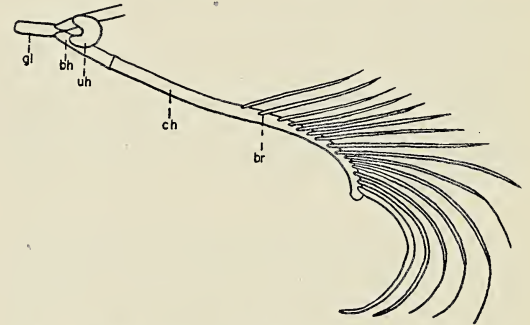


FIG. 4. Right side of hyoid arch, from below. bh, Basihyal; br, branchiostegal ray; ch, ceratohyal; gl, glossohyal; uh, urohyal.

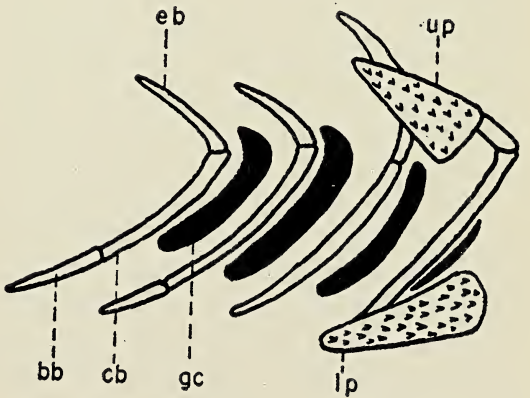


FIG. 5. Median view of right gill arches, somewhat opened out. bb, Basibranchial; cb, ceratobranchial; eb, epibranchial; gc, gill cleft; lp, lower pharyngeal; up, upper pharyngeal.

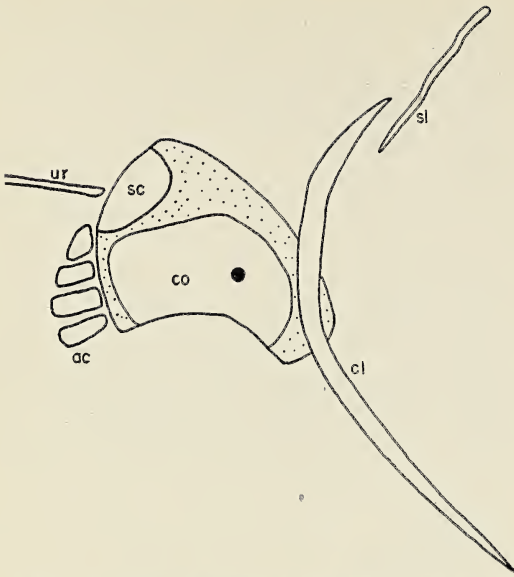


FIG. 6. Lateral view of right side of pectoral girdle. Cartilage stippled. ac, Actinost; cl, cleithrum; co, coracoid; sc, scapula; sl, supracleithrum; ur, upper pectoral ray.

bear conical teeth. The openings between the first four gill arches are wide; that between the fourth and fifth is restricted.

The pectoral girdle of *Kaupichthys* (Fig. 6) is rather well developed for eels. The supracleithrum (sl) lies free in the flesh without articulation above or below. The cleithrum (cl) is a long, curved bone overlying the forward end of the endoskeletal girdle. The coracoid (co) and scapula (sc) are embedded in a cartilaginous plate. There are four actinosts (ac), of which three and a half articulate with the coracoid area.

The vertebrae number approximately 98. Of these, about 20 lie ahead of the anus. However, the numbers of preanal and abdominal vertebrae are not the same, for the coelomic cavity of this fish extends posterior to the anus, as does the portion of the vertebral column without closed haemal arches.

The short centrum (ce) of the first vertebra (Fig. 7a) has a rounded head fitting the socket of the basioccipital. It bears a neural arch (na), which extends backward over the

centrum of the second vertebra. The second vertebra, in addition to the neural arch, has a median ventral projection. The third is similar to the second but bears a well-developed transverse process pointing postero-laterally. The neural arches of the first few vertebrae have crests with two to several dorsal spinules. These small spines drop out behind about the fifth vertebra. Farther back along the vertebral column each neural arch gives rise to a neural spine, these becoming well developed over the middle of the caudal portion of the vertebral column, but diminishing again posteriorly, and dropping out completely over the last nine vertebrae.

Over the whole rear part of the abdominal section of the column the vertebrae develop broad, flat, lateral flanges. These, however, fail to bear ossified ribs. In fact, there appear to be no articulated ribs anywhere in the fish. Nevertheless, there are, in the caudal section, what appear to be long, slender, unarticulated epipleurals and epineurals for each vertebra (not shown in Fig. 7c).

Posteriorly the haemal canal seems to stop at the seventy-eighth vertebra. The haemal spines (Fig. 7c, hs) continue to the ninety-third. The final vertebra (Fig. 7b and d) is extremely elongate. It appears to be made up in part of a rudimentary centrum, with neural and haemal arch, and in part of endoskeletal elements (ee) of several fin rays. These endoskeletal elements form three groups united to the rest of the vertebra by a cartilaginous plate containing a large foramen (fo).

The heart lies just behind the gill arches and immediately before the level of the pectoral girdle.

#### RELATIONSHIPS

The osteology of *Muraenichthys* closely resembles that of the Ophichthyidae (to be dealt with in a forthcoming paper) and differs vastly from that of *Kaupichthys* described above. The frontals of *Muraenich-*



*thys* are fused; the orbitosphenoid is short and rounded; the otic bulla is little developed; the parietals and pterotics are far smaller; the suspensorium is somewhat forwardly inclined; and the branchiostegal rays are long, fine, and numerous. Still other differences between the two genera are to be found in the pectoral girdle and vertebral column.

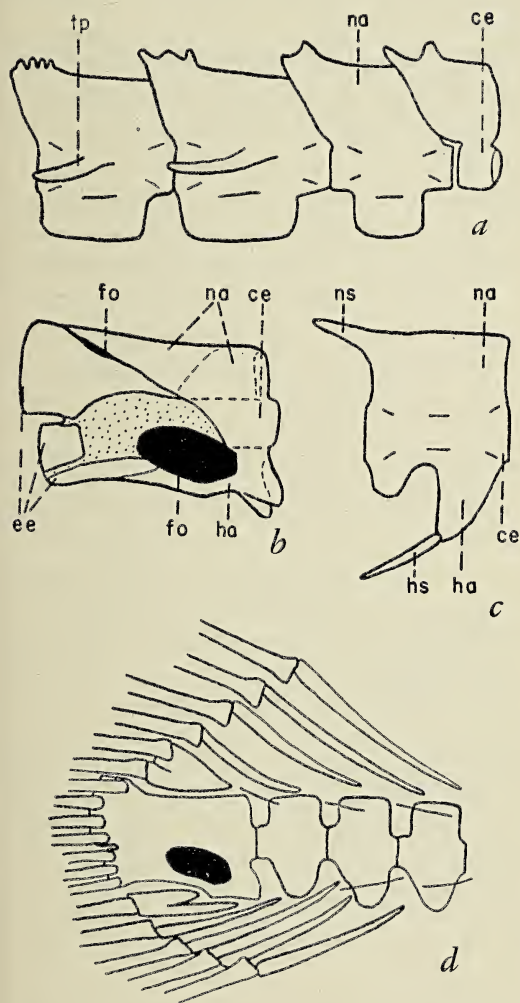


FIG. 7. *a*, First four vertebrae, lateral view of right side; *b*, terminal vertebra (cartilage stippled); *c*, seventy-ninth vertebra; *d*, last four vertebrae plus endoskeletal elements and bases of exoskeletal elements of fin rays; ce, Centrum; ee, endoskeletal elements of fin rays; fo, foramen; ha, haemal arch; hs, haemal spine; na, neural arch; ns, neural spine; tp, transverse process.

Since both *Muraenichthys* and *Kaupichthys* have always been included in the Echelidae, a question of the allocation of the family name arises. It is obvious from Regan's diagnosis (1912: 380 and 386) of his family Echelidae that he investigated the *Muraenichthys* type of eel. On the other hand, from the descriptions of *Echelus myrus*, the genotype of *Echelus*, given by Richardson (1844: 108), Günther (1870: 50), and Jordan and Davis (1892: 642), it appears that the family name Echelidae belongs with *Kaupichthys*. The *Muraenichthys* type can probably best be placed within the Ophichthyidae, following the suggestion of Myers and Storey (1939: 157), as a subfamily, Myrophinae. However, the final applications of the names Echelidae and Myrophinae (or Myrophidae) must await an osteological examination of *Echelus myrus*, a Mediterranean species unavailable to me.

The family Echelidae in the sense used just above, i.e., limited to the *Kaupichthys* type of eel, shows distinct relationship to the Moringuidae and Heterenchelidae in the paired frontals, and particularly in the enlarged otic bulla. It differs from either of the latter families in possessing relatively high vertical fins and labial posterior nostrils. It resembles the Heterenchelidae but not the Moringuidae in the long, narrow orbitosphenoid, in the laminar palatopterygoid, in having the trunk shorter than the tail, and, apparently, in the movable articulation between the first vertebra and the skull. It resembles the Moringuidae but not the Heterenchelidae in lacking a suture between the ethmoid and the vomer. Thus the relationships of *Kaupichthys*—and provisionally of the Echelidae—are closest with the Heterenchelidae.

The fact that *Kaupichthys* and *Muraenichthys* belong to different families also raises the problem of the family allocation of the remaining genera assigned to the Echelidae *auctororum*. Some, such as *Garmanichthys*, appear to belong with *Kaupichthys*. Others,

for example *Myrophis*, are of the *Muraenichthys* type. The superficial similarity between the two groups makes the problem of properly placing the genera particularly complex. Both have no free tongue, have the posterior nostril on the upper lip, the dorsal and anal confluent around the tip of the tail, and the gill opening consisting of a small hole. Within the Myrophinae the position of the anus and of the origin of the dorsal vary considerably, and the pectoral fin may be present (as in *Myrophis*) or absent (as in *Muraenichthys*); consequently these characters cannot be used to separate the Myrophinae from *Kaupichthys*.

The only superficial distinction that I can find between the groups is the presence in the Myrophinae of a swollen gullet supported by a basket-like arrangement of the numerous, long branchiostegal rays (Parr, 1930: 71), and the absence of these characters in the *Kaupichthys* type of eel. Other distinguishing external characters could probably be found if adequate comparative material were available.

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# The Genesis and Morphology of Hawaiian Ferruginous Laterite Crusts<sup>1</sup>

G. DONALD SHERMAN<sup>2</sup>

MASSIVE FERRUGINOUS SOIL HORIZONS have been discovered in the profiles of certain Hawaiian soils which have morphological characteristics similar to the ferruginous laterite crusts found in other tropical areas. Likewise, the nature of the soil weathering responsible for these ferruginous horizons bears a great resemblance to that described for other ferruginous horizons. However, the ferruginous soil horizons found in the Hawaiian Islands do not have the hardness which is described for ferruginous crusts in India or Indo-China. In spite of the lack of this degree of hardness the author feels that the Hawaiian soils which have a hard ferruginous surface or near-surface horizon are the equivalent of the ferruginous laterite crust of other tropical regions. It is the purpose of this article to describe the genetic and morphological characteristics of the Hawaiian laterite crusts and to show their similarity to other described laterite crusts.

The original description of a laterite was made by Buchanan (1807), who defined it as a ferruginous indurate clay which is brick-like in nature. Pendleton (1946), a firm follower of Buchanan, has defined a laterite as follows: "Illuvial horizon largely iron oxides, slaglike, cellular or pisolitic structure, and of such a degree of hardness that it may be quarried out and used for building construction." Many of the temples in tropical Asia are built of these laterite materials. Du

Preez (1949) has modified Pendleton's definition in that he describes a laterite to be a vesicular, concretionary, cellular, vermicular, slaglike pisolitic or concrete-like mass consisting chiefly of ferric oxides with or without mechanically entangled quartz and minor quantities of alumina and manganese; it is of varying hardness but it is usually easily shattered when struck a sharp blow with a hammer. Du Preez's definition differs from Pendleton's in that it does not require a degree of hardness to meet the requirements of a material suitable for building construction. Botelho da Costa and Lobo Azevedo (1949) have objected to a definition of a laterite which requires the presence of a concretionary ferruginous layer. In general, Du Preez's definition has considerable acceptance.

Sherman (1949) has pointed out that the laterite crust will be the end product of tropical soil weathering under an alternating wet and dry season. He has suggested that under continuous moist soil conditions the ultimate end product of soil weathering in the tropics will probably be a soil rich in alumina. The ferruginous layer which occurs at or near the surface is called a laterite crust in that it is usually a hard sterile soil area. The ferruginous layer may be found below the surface which may have resulted from erosion or by formation over the water table in coarse-textured soils. The ferruginous layer which develops in the fine-textured soils materials forms below the surface and is later exposed by erosion as sterile hard surface soil.

## HAWAIIAN LATERITE CRUSTS

Hawaiian soils having hard sterile surfaces have been described by Sherman *et al.*

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<sup>2</sup>Chairman, Department of Soils and Agricultural Chemistry, University of Hawaii Agricultural Experiment Station.

(1949). These soils have a surface horizon which is a compacted or vesicular slaglike mass having a very high apparent specific gravity. Some of these areas are covered with a sparse dwarfed vegetation while others are practically barren areas in which the surface soil has a glazed surface with the hardness of a pavement. The high apparent specific gravity is due to presence of large quantities of iron and titanium oxides which make up more than 75 per cent of the soil. The hard sterile ferruginous laterite crusts have been found on the southern and western slopes of the island of Kauai; on the western slope of the main mountain range of Molokai; and on the white trachyte cliffs of West Maui. In every case the areas are found on long slopes in which heavy rainfall is received at the higher elevations while the lower elevations remain very dry. The areas of hard crusts are found just below the lower boundary of the canopy forest.

#### MORPHOLOGICAL DESCRIPTIONS OF HAWAIIAN LATERITE CRUSTS

##### *Island of Kauai*

The hard sterile laterite crusts are found on the southern and western slopes of leeward Kauai. These areas are found on the benches or on broad and more level areas of the long ridges which run from the top of the mountains toward the ocean. The hard surface crusts are found in the transition zone between the shrub vegetation on the lower elevations of the slope and the dense canopy forest cover on the wet higher elevations of the slope. The surface horizon of the crusted areas is a very hard compacted purple silt loam having a very high apparent specific gravity. The volume weight of this layer approaches 3.0 in some cases. This horizon is very hard and it is necessary to use a heavy sharp tool to break the layer. The chipped-off fragments crush readily in one's hand to a very fine graphite-like powder. This pow-

dery material contains small pellets of magnetite. About 30 per cent of the particles are of clay size, but even so this material does not exhibit any evidence of stickiness when wet. The thickness of the crust may vary from 4 to 14 inches.

The hard surface layer is underlain by a yellowish-brown to reddish-brown friable silt loam. There is very little evidence of heavy minerals which were responsible for the high apparent specific gravity of the surface horizon. While this soil has the physical properties of a silt loam, mechanical analysis of the soil showed that more than 60 per cent of the soil particles are of clay size. The thickness of the friable layer ranges from 12 to 36 inches.

The friable layer lies over an impervious surface of an unconformity or an impervious soil horizon. In the former case the material is of different geological formation than the material from which the soil was formed. In the latter case it has not been established whether the impervious soil horizon is related to the soil solum or is the surface of a buried soil. Whether or not this plastic subsoil is related to the soil, it has provided an impervious layer which, apparently, is necessary for the formation of ferruginous laterite crust.

The chemical analysis of a typical Kauai ferruginous laterite crust is given in Table 1. The high content of iron and titanium oxides in the hard crusted surface horizon is characteristic of these soils. The iron oxide exists as hematite, and titanium oxide as anatase.<sup>3</sup> Another characteristic of the analysis of this horizon is the low content of volatile matter. The B horizon has an iron oxide content ranging from 70 to 80 per cent. The iron oxide of this horizon exists as goethite and hematite. The titanium oxide content of this layer is markedly lower than is that of the hard surface horizon. The chemical composition

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<sup>3</sup>Cooperative studies with Dr. M. L. Jackson, University of Wisconsin.



TABLE 1  
THE CHEMICAL COMPOSITION OF A TYPICAL FERRUGINOUS LATERITE PROFILE. THIS PROFILE IS  
LOCATED OFF THE KOKEE ROAD ON KAUAI

HORIZON	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>
<i>inches</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Surface 0-3	10.8	10.7	38.2	19.4
Ferruginous Crust 3-11	3.8	9.9	47.5	25.1
Friable Layer 11-27	5.5	7.6	78.5	7.2
Plastic Clay 27+	22.8	21.7	35.4	3.3

of the impervious horizon is very different from that of the other two horizons. The higher content of both silica and alumina indicates the presence of aluminosilicate clay minerals.

*Island of Molokai*

The hard, compacted, ferruginous laterite crusts are found on the westerly slopes of the mountain range. The areas of this soil are found in the zone of the open forest, just below the heavier canopy forest of the wetter, higher elevations. These areas are easy to observe because of their distinct purple color and shiny glazed surfaces. The hard surface layers of these laterite crusts are harder and more compacted than are those found on Kauai. The areas of this soil are limited to a very narrow belt on Molokai, whereas the laterite crusts are found over a much wider area on Kauai. The hard surface crust of these soils is very similar to those found on Kauai. The chief profile difference occurs in the friable layer. The friable layer below the hard surface horizon of the Molokai laterite crusts is very thin, ranging from 4 to 8 inches. In every observed instance the friable layer lies over a solid rock formation.

The physical and chemical compositions of the Molokai laterite crusts are very similar to those of the Kauai laterite crusts. The iron oxide content of the surface ranges from 48 to 65 per cent and the titanium oxide from

20 to 24 per cent. Likewise, the volatile matter ranges from 3.2 to 4.2 per cent. The iron oxide content of the friable layer ranges from 70 to 76 per cent.

*West Maui*

The ferruginous laterite crusts of West Maui occur as erosion remnants on the white trachyte cliffs. These areas are easily seen from an airplane. From the highway these areas can be seen as red caps on top of the grayish-white ridges running up the mountain slope. These areas are so badly eroded that in only a few locations does the profile remain intact. In one case the hard surface crust has slid away from its friable layer and the two now exist as separate erosion remnants.

The hard surface horizon is a compacted, reddish silt loam having a high apparent specific gravity but lower than that found for Kauai and Molokai laterite crusts. The surface of these crusts is hard but does not have the shiny glazed surface of the two other areas. The clay content of this horizon is higher, being more than 35 per cent.

The friable layer of these soils has all the characteristics of the Kauai profile. It is very ferruginous and has a clay content exceeding 65 per cent. The thickness of the friable layer has been found to range from 12 to 30 inches.

TABLE 2  
THE CHEMICAL COMPOSITION OF TYPICAL HAWAIIAN FERRUGINOUS LATERITES  
AND SIAM FERRUGINOUS LATERITES\*

LOCATION OF FERRUGINOUS LATERITE	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	TOTAL
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Kauai—Waimea Canyon	3.9	5.8	60.8	26.0	96.5
Molokai—Just below forest line	7.8	3.6	60.4	24.0	95.8
Maui—From eroded trachyte cliffs	5.8	12.0	64.8	11.2	93.8
Siam—Ferruginous concretion	11.8	30.0	46.2	1.8	89.8
Siam—Ferruginous lens	15.4	24.8	51.2	2.4	93.8

\* Samples of Siam ferruginous laterites were given to the author by Dr. R. L. Pendleton. The sample analyzed was from a portion of the specimen showing the greatest evidence of iron deposition.

These soils have developed from the trachyte rock on which they are found. Even though these are residual soils, there is a sharp boundary between the unweathered trachyte rock and the soil solum.

The chemical composition of the ferruginous laterite crust from West Maui is given in Table 2, along with the analysis of ferruginous laterite horizons from Kauai and Molokai. Also included in Table 2 are samples of Siam laterites. The difference in the analyses indicates that Siam is not as old as the areas on Molokai and Kauai, or that the difference may be due to the nature of the more acidic parent material. Some of the crusts which occur at inaccessible higher elevations appear to have progressed further in their development than those at the accessible lower elevations.

#### SOIL WEATHERING CYCLE INVOLVED IN FERRUGINOUS LATERITE CRUST FORMATION

The ferruginous laterite crusts have developed in Hawaii under certain definite weathering conditions. It has been pointed out that the ferruginous laterite crusts have formed on long slopes which have a heavy annual rainfall region at the higher elevations and a low annual rainfall at the lower elevations. Certain other characteristics always appear to be necessary for the crust

formation. The impervious layer, whether an unconformity or impervious clay layer, is always found below the friable horizon. If one examines the lower portion of the friable layer, indications of the lateral movement of water will be observed. This has been substantiated by the very wet condition found in this layer at a period of several days after heavy rainfalls at the higher elevations. The lateral movement of water through the friable layer has been demonstrated by the seepage of water into wells dug in this type of a soil. The hard crust surfaces are formed in areas of the slope which are either a bench or the more level areas of the slope. The last condition, a very important one, is that the crusts are formed in a climatic region which has a very dry season alternating with a wet season. The greatest development occurs in the regions where the wet and dry seasons are of about the same duration. A typical case would be 4 months with less than 2 $\frac{3}{8}$  inches of rainfall and 3 months having more than 4 inches of rainfall. Some of the dry months may have less than an inch of rainfall; thus, the vegetation of the area will be the type which falls between the shrub vegetation of the drier areas and the tropical canopy forest of the wetter areas.

The two factors which appear to be most responsible for the development of the



crusted surface horizons are the lateral movement of water through the friable layer and the alternating wet and dry season. The water moving laterally through the friable layer would contain dissolved ions from the weathering of the soils under a heavy rainfall condition where the soil solum is continuously moist. Sherman (1949) has shown that in these soils iron oxides are being reduced and are being leached away in the percolating water. He also pointed out that titanium content of these wet soils is low as compared to other Hawaiian soils. Thus it is possible for the percolating waters of these soils to contain iron in a reduced form and titanium as a hydrated titanium oxide or in an acid form. The former has been identified by Doelter (1913) in laterite soils, and the latter is possibly due to the very acid condition of the soils of the very wet locations. The waters would also contain a small amount of dissolved silica. The greater portion of the silica is removed during the earlier stages of soil weathering and when the internal drainage of the soil profile was good. As the soil matured, the internal drainage became poor due to the development of impervious clay layers. With the development of the poor internal drainage more of the percolating water will move down the slope laterally and less will percolate through the soil and its weathered parent material. When the lateral movement of percolating water reaches areas having an alternating wet and dry season, conditions become favorable for the capillary rise of the percolating waters during the dry season. The capillary rise of the percolating waters to the surface is greatly enhanced by the benches or level areas of the slopes. A similar case of enrichment of soils of lower elevations by lateral movement of percolating waters has been proposed by Green (1947).

The dissolved iron and titanium are brought to the surface in the capillary water. The iron is stabilized by its oxidation to the

ferric form. During the dry season the iron oxide, which probably exists as goethite, and the hydrated titanium oxides are dehydrated to form the minerals hematite and anatase, respectively. The dissolved silica in the percolating waters would probably rise to the very surface before dehydration. The data in Table 1 would support this hypothesis. The lack of an appreciable amount of titanium oxide in the friable layer would suggest that the titanium must move as a colloidal hydrated titanium oxide. Fujimoto *et al.* (1949) have reported the titanium oxide content of 45 per cent in the colloidal fraction of the transitional zone between the friable layer and the laterite crust horizon. The low content of volatile matter, which would include water of hydration, suggests that both titanium and iron oxides are stabilized by dehydration. This would account for the presence of the two secondary minerals hematite and anatase in the surface soil. The ilmenite content of these soil horizons is extremely low and would rule out the possibility of residual concentration. Furthermore, if ilmenite did not decompose under tropical soil weathering, titanium should be concentrated in greater quantities in the surface horizon of the soils developed in the regions of heavy rainfall as well as where it is found in the area having the hard surface crusts. The chemical analyses of these soils do not reveal a concentration of titanium. In Figures 1 and 2 are given the graphical representation of the manner in which the ferruginous laterite crusts have become the zone of accumulation of iron and titanium oxides.

The ferruginous laterite crust is considered to be the senile stage of tropical soil weathering under a climate having alternating wet and dry seasons. Thus as the crust area becomes denuded of vegetation it will remain a stabilized land form until removed by erosion or degraded into another condition by general advancement of age of the general land area. The laterite crusts are very suscep-

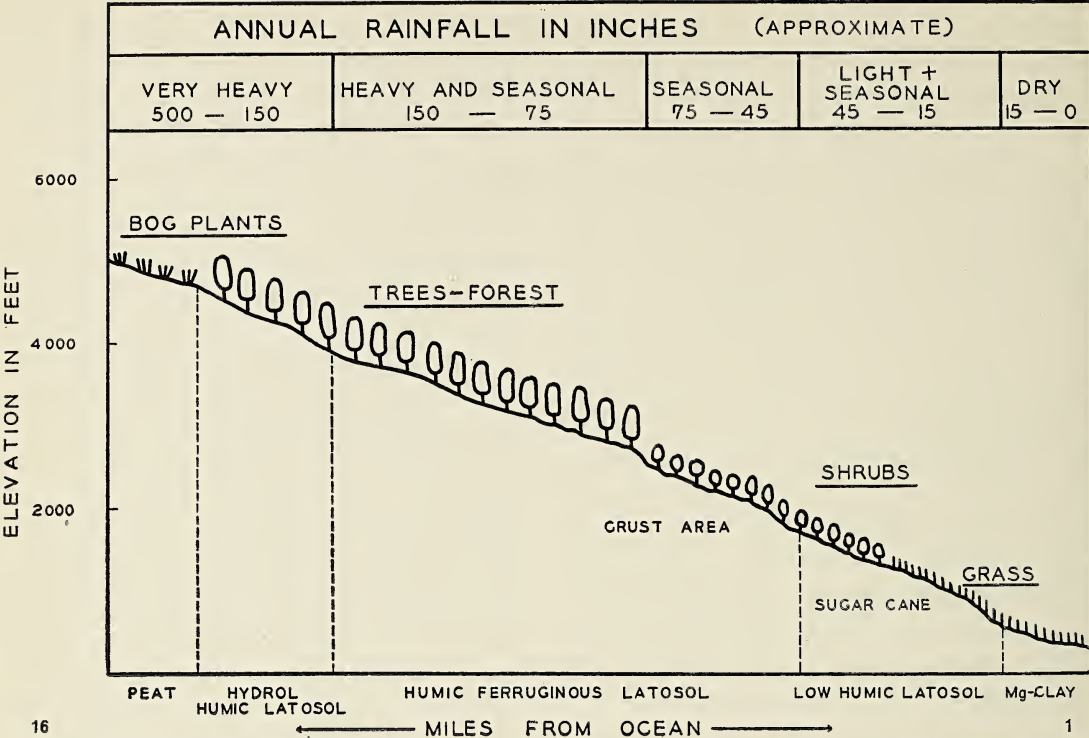


FIG. 1. The location of the ferruginous soils in relation to rainfall distribution, elevation, and vegetation zones.

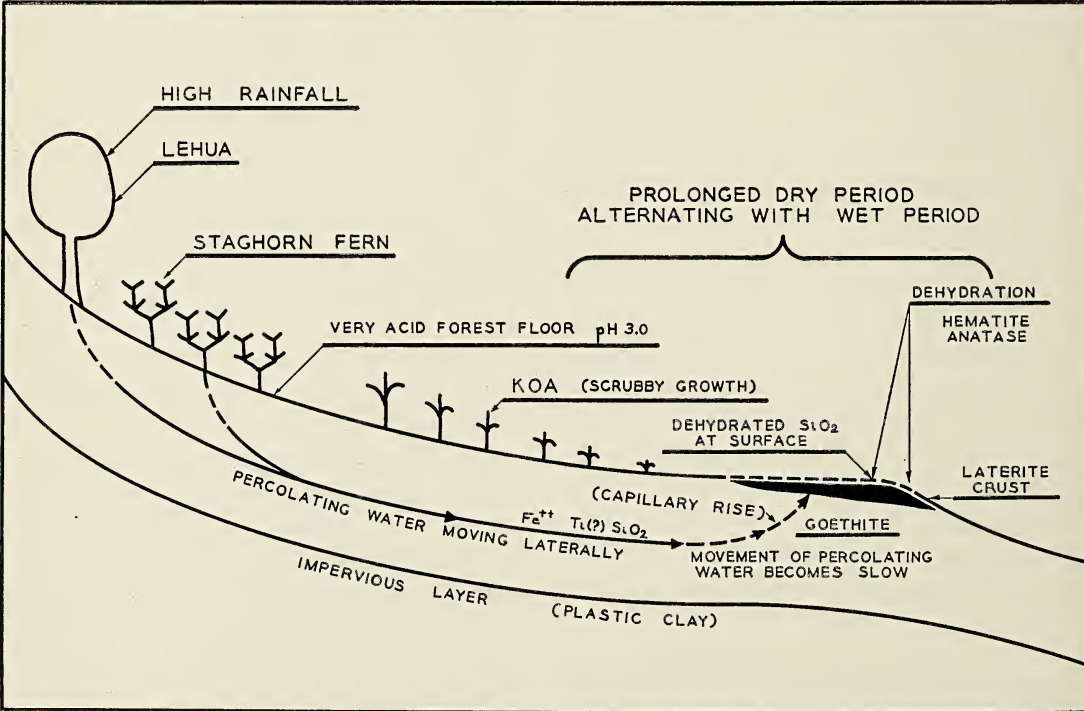


FIG. 2. The location of the ferruginous laterite crust in relation to lateral movement of water from wetter higher elevations.



TABLE 3  
THE CHEMICAL COMPOSITION OF A DEGRADED FERRUGINOUS LATERITE PROFILE  
FROM LIHUE, KAUAI

HORIZON	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>
<i>inches</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Former ferruginous crust 6-18	28.5	25.8	9.9	24.4
Former friable layer 22-30	32.0	33.2	13.4	7.6

tible to erosion due to the underlying friable layer. Any break in the crust will permit the initiation of erosion by the removal of the friable soil, thus undermining the hard surface layer. Eventually fragments of the hard surface layer will break off. Erosion will eat rapidly into an area and soon only remnants of the original hard surface will remain. The area found on the white trachyte cliffs of West Maui is a good example of this type of erosion.

When the laterite crust is developed in an area which is becoming nearly a peneplain, that area will undergo degradation. In this case the internal drainage becomes restricted and the soil solum is moist or saturated with water during most of the year. Under these conditions the free iron oxides become unstable and are reduced and leached away in the sluggish percolating waters. Titanium oxide will remain quite stable. The profile becomes enriched with colloidal materials and silica from the slow-moving ground waters of the higher elevations. Thus resilication will take place giving rise to a skeleton crust which is rich in silica, alumina, and titanium oxide and low in iron oxide. A typical analysis of a degraded laterite crust is given in Table 3. The data show an iron oxide content of 9.9 per cent and a titanium oxide content of 24.4 per cent in the surface layer of this former ferruginous laterite crust.

SUMMARY

The ferruginous laterite crust has developed in three general areas of the Hawaiian

Islands; namely, the southern and western slopes of leeward Kauai; the westerly slopes of the main mountain range of Molokai; and on the white trachyte cliffs of West Maui. The ferruginous laterite crusts are found on the long slopes which have a region of very high rainfall at the higher elevations and a semi-arid condition at the lower elevations. The areas of ferruginous laterite crusts are located at higher elevations which have a definite alternating wet and dry season.

The ferruginous laterite crust profiles have a hard slaglike surface horizon having a very high apparent specific gravity. This layer is underlain by a friable layer of a thickness varying from 4 to 36 inches. This always lies over an impervious layer of either rock or a plastic clay. The hard surface horizon is rich in iron and titanium oxides and very low in volatile matter. The friable layer is made up of iron oxides, which sometimes constitute as much as 80 per cent of the soil.

A hypothesis is advanced as to the genesis of these ferruginous laterite crusts. This proposes that iron and hydrated titanium oxides in the percolating waters from the soils developed on the wet areas of the higher elevations move laterally over the impervious subsoil layers and subsequently accumulate in the surface horizon by capillary action in regions having an alternating wet and dry season climate. The hydrated iron oxide and titanium oxides are stabilized by dehydration and are converted to hematite and anatase in the surface horizon. This gives rise to a

hard compacted surface horizon with a very high apparent specific gravity.

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# Life History and Feeding Habits of the Giant African Snail on Saipan<sup>1</sup>

W. HARRY LANGE, JR.<sup>2</sup>

THE GIANT AFRICAN SNAIL, *Achatina fulica* Férussac, has recently received considerable attention as an economic threat to the people occupying certain islands included in the Trust Territory of the Pacific Islands because of its catholic taste for fruits and vegetation. In addition, its introduction (but not its establishment, to date) into California on heavy equipment returned from Pacific islands has brought to our attention its status as a potential threat to agriculture in the continental United States.

*Achatina* is very abundant on Saipan, where it causes extensive damage to many types of fruit and vegetable crops. The present study was an attempt to secure additional information concerning its habits, life history, feeding preferences, natural enemies, and seasonal activity. This information may prove of value not only in relation to the possible introduction of natural enemies, but also in determining the economic potentialities of this snail should it ever become established on the mainland of the United States. During this study an opportunity was available to make limited observations of this snail in the Philippines (Luzon), Siam, Malaya, and Java. A survey was made of the other terrestrial and fresh-water snails of Saipan inasmuch as a knowledge of these

species is an important adjunct to a biological or chemical control program.

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## DISTRIBUTION

This is a species which is native to the east coast of Africa, from Natal and Mozambique in the south to Kenya and Italian Somaliland in the north<sup>3</sup> (Mead, 1949:38); from there

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<sup>1</sup>These investigations were undertaken as a project of the Pacific Science Board of the National Research Council under the direction of their Insect Control Committee for Micronesia. These studies were aided by a contract between the Office of Naval Research, Department of the Navy, and the National Academy of Sciences (NR161 472).

<sup>2</sup>Assistant Entomologist, Division of Entomology and Parasitology, University of California, Davis, California. Manuscript received February 9, 1950.

<sup>3</sup>Bequaert (personal communication, February 14, 1950) reports that the known distribution is only from northern Mozambique (17° S.) in the south to southern Abyssinia and the southern half of Italian Somaliland in the north (7° 30' N.). Inland it extends 150 to 500 miles from the coast, going farthest inland in the northern section of the range.



it has spread through many tropical and subtropical areas. It was introduced to Mauritius (1803, or before), later to Seychelles, and about 1847 was introduced to Calcutta, India (Jutting, 1934:43). Several authors report its spread from India (Jarrett, 1931:263; Jutting, 1934:43; and Mead, 1949:38-39). In 1900 it appeared at Ceylon, and in 1911 was present at Singapore and later in other Malayan localities. In Borneo (Sarawak) it appeared in 1928 and in 1933 its presence was noted in Java and Sumatra. It appeared at Amoy, China, in 1931 and was recorded at Hong Kong in 1937.

The Japanese apparently hastened the spread of the African snail during their Pacific campaign because they carried snails as a supplementary diet from one island to another. The snail was undoubtedly present on certain of the islands before the war, but on others had not been introduced. As a result, the snail became more widely distributed in the Dutch East Indies, particularly in New Guinea, New Britain, and New Ireland. It appeared in the Philippines and is known from the Bonin Islands.

In Micronesia, Townes (1946:15-16) reported *Achatina fulica* from Saipan, Tinian, Rota, and Guam in the Marianas and from Koror, Ponape (near Colonia), southern Babelthuap, Peleliu, and part of Truk (Dublon) in the Carolines. T. R. Gardner (personal communication) supplied more detailed information regarding its distribution in the Palau Islands as follows: Angaur, Malakal, Koror, Arakabesan, and the south half of Babelthuap. Mead (1949:39) reported it at Pagan in the Marianas. Reliable natives on Saipan report that the snail has been present on the island for about 10 years. It had also been reported from Pagan prior to the Pacific conflict.

In the Philippines this snail was very common on October 22, 1947, at Los Banos, Luzon, feeding upon papaya fruits. It was found by the writer in southern Siam, north

of Haadjai, on December 8, 1947. In Malaya it was a common, but non-destructive, mollusk in the Port Swettenham region near Klang.

#### DESCRIPTION

The degree of variation in shell size and markings and the internal anatomy of *Achatina fulica* are described by Tryon and Pilsbry (1904-05:55-58).

On Saipan typical shells are dull whitish, yellowish, or gray-tan, with characteristic transverse dark brown to purplish-brown streaks. Transverse dark markings are more prevalent in juvenile specimens. In older individuals the first whorls become white to gray and the body whorl often becomes a uniform tan devoid of transverse markings.

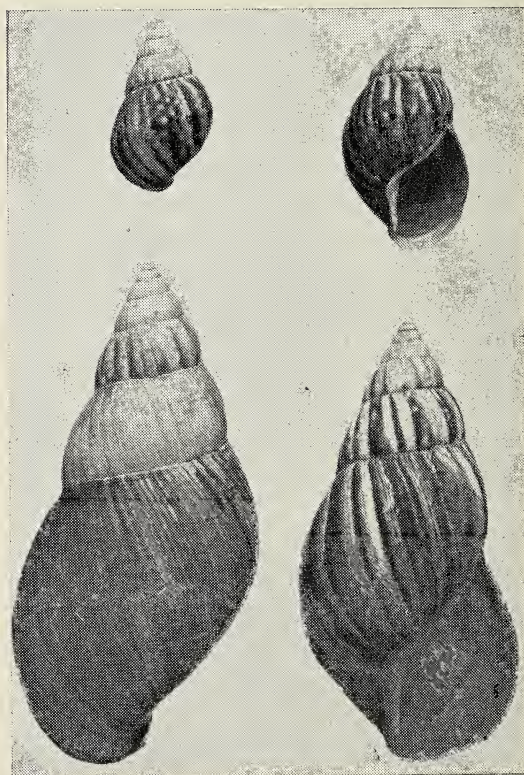


FIG. 1. Shells of *Achatina fulica*: above, juvenile specimens, Saipan, November 3, 1947; below, left, specimen from Rota, March 16, 1948, showing reduction of dark bands; right, typical Saipan specimen, November 3, 1947.



Average specimens are smaller than on Guam, ranging from 2.5 inches to 3.75 inches long. Differences in markings are shown in Figure 1. The shell whorls have transverse striations and microscopic, spiral striae. The animal is gray-tan to black.

Shells often show whitening and, in some individuals, complete loss of color. This condition was quite prevalent on parts of Rota. Many shells show scratching of the surfaces as if caused by burrowing in the soil or by crawling under objects on the surface of the soil. On Saipan an abnormal condition of many shells was observed, namely, the presence of a thin, paper-like shell, easily broken by handling. Shells of normal thickness are found in the same area, but there are areas, such as Marpi Point on the north end of the island, where normal shells are more commonly found. This condition could be a genetic one concerned with carbonate metabolism, or could be a result of the availability of carbonates in particular areas.

LIFE HISTORY AND DEVELOPMENT

Inasmuch as the life history and development of the snail on Saipan deviates to some extent from other published reports, a few salient records will be cited. Jarrett (1931: 263) reported that in China the African snail laid 100 eggs the first year, 200 to 300 eggs the end of the second year, and produced 1,000 eggs during a 3-year period. He stated that in Malaya egg laying occurred during March, April, and May. The same writer stated that in Borneo eggs were laid in October, and probably throughout the year.

Green (1911:43) concluded that *Achatina fulica* reached full growth in 2 years, but were sexually mature in 1 year, at which time they were about half grown. He did not record a maximum number of eggs, but stated that each snail deposited at least 100 eggs the first year and 500 the second year.

Pilsbry (1919:60-61) described the Acha-

tinae as oviparous, laying as many as 196 eggs in loose soil just beneath the surface.

The fact that *Archachatina marginata* lays eggs in trees is mentioned by Tryon and Pilsbry (1904:205).

D. B. Langford (personal communication) recorded the time interval from egg to sexual maturity as 147 days on Guam. Measurements of Langford's reared specimens on deposit at the Hawaiian Sugar Planters' Association Experiment Station, Honolulu, are tabulated here:

AGE weeks	NUMBER OF WHORLS	LENGTH mm.
1	3	5
2	3.5	8
3	4	12
4	5.5	26
5	6.5	34
6	6.5	40
7	7.5	63

Mead (1949:40) recorded male sexual maturity before the snail is a year old; development of female organs and egg deposition takes a few months longer. The same author also reported retention of the eggs inside the uterus so that eggs hatched within a few hours, but this phenomenon was not observed during the present observations.

On Saipan the eggs are nearly globular, approximately 4 mm. by 5 mm. in size, white when first laid but later turning yellowish. When first laid they are covered with a clear mucus which gives them a glistening appearance. In a few hours the mucus dries and the eggs become a dull white. Eggs are shown in Figure 2.

This snail is hermaphroditic, although reciprocal mating occurs and both individuals lay eggs. Snails mate chiefly at night, but on Saipan mating was continued during the day, particularly if the weather was rainy or overcast. Snails mating under the protection of dense jungle cover or creeping vines often continued to mate during the day. Snails often started to mate in the late afternoon,





FIG. 2. *Achatina fulica* and eggs, Saipan, October 29, 1947.

and it was noted that individuals crawling about in trees during the day occasionally extruded the genital organs.

In mating one snail usually climbs above another, the organs are interchanged, and both snails fall to one side, remaining together for a period varying from less than 1 hour to 24 hours or more. The manner of mating is shown in Figure 3. Snails collected during coition were held in the laboratory in gallon cans which had been filled with 4 inches of moist soil. After mating, eggs were deposited in from 8 to 20 days, with an average interval of 10 to 12 days. On Saipan a preferred site for egg deposition was under loose soil at the bases of breadfruit trees as shown in Figure 4. Eggs were also laid under rocks, boards, or other objects, or in the soil wherever there was a cover of vines, shrubs, or trees. Eggs were often merely scattered about on the surface of the soil or barely cov-

ered, and rains often exposed many of these. Usually a snail made a depression about 2 inches wide by 1.5 inches deep in loose soil in the ground, deposited its eggs, and covered them with soil.

Egg masses were found in the field from October 16, 1947, to November 11, 1948. The presence of young snails on October 16, 1947, indicated that eggs had been laid prior to this time. The number of eggs laid in the field varied from 93 to 184, with an average of 139 eggs. In the laboratory, egg deposition was observed from October 30, 1947, to November 19, 1947; the eggs were laid in gallon cans filled with 4 inches of soil. The number of eggs laid by individual snails in the laboratory varied from 62 to 243, with an average of 129 eggs.

In captivity most of the snails laid their eggs during one night, but occasionally an



individual would lay a few eggs at a time over a period of several nights.

The length of the egg period in the laboratory on Saipan varied from 6 to 12 days with a mean average period of 8.8 days. In the field the egg period was approximately 11 days. It was noted that under field conditions there was a high incidence of infertility which was not true under laboratory conditions. For this reason failure to hatch under field conditions was attributed to desiccation or other adverse exposure to environmental factors.

After hatching, the young snails began to devour the egg shells and ordinarily remained together in a group feeding on the shells during a 3- to 4-day interval. After this time they scattered, seeking other food. On the day of hatching snails were placed

drinking water was found to affect young snails adversely. During these observations, which extended over a 5-month period, snails increased in size from 2.5 whorls at hatching to 6.5 whorls. Of 20 individuals observed from October 31, 1947, until April 4, 1948, only eight were successfully reared. The following tabulation gives a summary of the information obtained.

TIME EXAMINED	AVERAGE WEIGHT <i>grams</i>	AVERAGE WHORLS <i>number</i>
At hatching	0.04	2.5
25 days	0.22	4.0
60 days	2.14	5.0
121 days	6.37	5.5-6.0
156 days	8.96	5.5-6.5

These rearings are not considered indicative of the rate of growth under field conditions inasmuch as snails were fed irregularly



FIG. 3. *Achatina fulica* mating on ground in jungle area near Klang, Malaya, January 2, 1948.

in cans approximately 4 inches wide by 6 inches deep and growth was observed in the laboratory. They were fed upon pieces of potato or breadfruit, and 1 gram of powdered calcium carbonate was placed in each can to assist in shell formation. Distilled water was used, inasmuch as the ordinary chlorinated



FIG. 4. *Achatina* clustered about the base of a breadfruit tree—a favorite site for egg deposition. Saipan, October 19, 1947.



during a 2-month period when I was in the field. The average weight increase was from 0.04 gram at hatching to 14.7 grams at the end of 156 days. This was an increase in weight of from 63 to 368 times above the initial weight, depending upon the particular snail involved. These rearings suggest that individuals vary greatly in their rate of growth, that weight can be lost when food or water is withheld, and that whorls are added regardless of the presence of adequate food. Mature, pregnant snails were found in the field which were 2.25 to 3.5 inches long, having 7 to 7.5 whorls.

It was noted that under field conditions there was a definite correlation between egg laying and wet and dry periods. Egg laying occurred during the wet season. During the dry season no eggs were laid and many snails secreted brown to whitish epiphragms and became inactive. On October 28, 1947, eight of the 50 snails examined in an area under

breadfruit trees were pregnant. On November 11, 1947, observations made in the same area showed that of several hundred examined only three were pregnant. Of hundreds of snails examined during the period from February 6, 1948, to April 4, 1948, no pregnant snails were found on Saipan. The location of observations apparently influenced the relative percentages of pregnant snails, because, of several hundred snails examined on November 3, 1947, at Marpi Point, Saipan, feeding on *Operculina turpethum* along a roadway, not a single pregnant snail was found. Snails seeking sites for oviposition were found more frequently in more protected areas.

Ordinarily there is a wet and a dry season on Saipan, although this may not be marked inasmuch as rain can fall during any month. There is also considerable variation, depending upon where the observations are made. The wet season is from July to November



FIG. 5. *Operculina turpethum*, a preferred food plant of *Achatina*; Saipan, March 18, 1948.



and the dry season from January to May. The mean average temperature at Tanapag during 1947 varied from 79.7° F. in January to 82.7° F. in August. This small difference would not materially influence activities of the snails. The relative humidity is high all year around, averaging 82 per cent. Records kept at Tanapag during 1947 gave an average of 80 per cent relative humidity during an 8-month period.

Rainfall apparently influences activities of the snails more than any other single factor. The record of the total monthly precipitation at Tanapag during 1947 and part of 1948 is as follows:

MONTH	RAINFALL inches	
	1947	1948
January . . . . .	2.45	4.47
February . . . . .	1.12	1.48
March . . . . .	1.40	3.68
April . . . . .	1.26	4.52
May . . . . .	1.90	2.53
June . . . . .	1.21	3.22
July . . . . .	7.80	
August . . . . .	4.93	
September . . . . .	5.49	
October . . . . .	15.20	
November . . . . .	4.00	
December . . . . .	1.42	

From January to June, 1947, there was a drought in Saipan, and the rainy season extended from July through November. Limited observations made on snail activity indicated that egg-laying periods were definitely correlated with periods of extensive rainfall, although feeding was possible at any time when moisture was present. This was also substantiated by an examination of the internal genital structures. Specimens collected during October and November had a full development of the female organs, whereas in specimens collected from February to April these structures were atrophied.

#### FEEDING HABITS

On Saipan the snail is omnivorous in its feeding habits, but is primarily a scavenger, preferring human and animal excreta, gar-

bage, decaying leaves, rotting fruits, crushed snails of its own kind, and soil. At night the crackling sound caused by the feeding of countless thousands of snails upon decaying leaves can be heard for considerable distances. In one instance 215 snails were counted feeding upon a single decaying breadfruit. Plane runways and roads where snails were crushed by traffic were favorite feeding sites for thousands of snails.

Of the fruits selected by *Achatina*, bananas (also the leaves and new shoots of banana trees), papayas, breadfruit, and ripe passion fruits were preferred. The snail caused severe damage to certain vegetables such as okra, Chinese cabbage, lettuce, melons, and yams. It also fed upon beans, carrots, corn, cucumbers, eggplant, pepper, pumpkins, radishes, squash, and watermelons.

An attempt was made to study the feeding preferences of the snail in relation to other types of vegetation. In general, snails preferred weeds and succulent plants to plants with thick, leathery leaves. In view of these findings the plants listed below will be separated into those preferred and readily eaten and those not readily eaten.

The preferred food plants of the snail on Saipan, together with the Chamorro name (if known) and the family, are listed below:

NAME	CHAMORRO NAME	FAMILY NAME
<i>Annona muricata</i>		Annonaceae
<i>Amaranthus</i>		
<i>spinosus</i>	kilitis	Amaranthaceae
<i>Albizzia lebbbeck</i>		Leguminosae
<i>Asplenium nidus</i>	galag	Polypodiaceae
<i>Blechnum</i>		
<i>pyramdatum</i>	yervas babui	Acanthaceae
<i>Canavalia</i>		
<i>gladiata</i>	gaye	Leguminosae
<i>Cassia</i>		
<i>occidentalis</i>		Leguminosae
<i>Colubrina asiatica</i>		Rhamnaceae
<i>Grewia</i>		
<i>marianensis</i>		Tiliaceae
<i>Ipomoea alba</i>	fofgo	Convolvulaceae
<i>Ipomoea</i>		
<i>pes-caprae</i>	halai hai	Convolvulaceae



<i>Melanolepis multiglandulosa</i>	alom	Euphorbiaceae
<i>Morinda citrifolia</i>	lada	Rubiaceae
<i>Operculina turpethum</i>	alag-alag	Convolvulaceae
<i>Passiflora foetida</i>	dulce	Passifloraceae
<i>Physalis peruviana</i>	tomates chaca	Solanaceae
<i>Pipturus argenteus</i>	atmahayan	Urticaceae
<i>Portulaca oleracea</i>	bordolagus	Portulacaceae
<i>Tectaria</i> sp.		Polypodiaceae
<i>Thespesia populnea</i>	pago	Malvaceae
<i>Vigna marina</i>		Leguminosae

Of the above plants certain ones are greatly preferred by the snails. These include *Passiflora foetida* (fruit and leaves); certain weeds such as *Blechnum pyramidiatum* and *Physalis peruviana*; creeping vines such as *Ipomoea alba* and *Operculina turpethum* (see Fig. 5); and *Melanolepis multiglandulosa* (which is also a preferred host plant of *Partula gibba*).

Certain plants which are fed upon only occasionally are:

NAME	CHAMORRO NAME	FAMILY NAME
<i>Bikkia mariannensis</i>		Rubiaceae
<i>Callicarpa cana</i>		Verbenaceae
<i>Capparis cordifolia</i>		Capparidaceae
<i>Cerbera manghas</i>	hunig	Apocynaceae
<i>Clerodendron inerme</i>		Verbenaceae
<i>Colocasia esculenta</i>		Araceae
<i>Ficus tinctoria</i>	hodda	Moraceae
<i>Hernandia ovigera</i>		Hernandiaceae
<i>Muntingia calabura</i>		Tiliaceae
<i>Ochrosia mariannensis</i>		Apocynaceae
<i>Ochrosia oppositifolia</i>		Apocynaceae
<i>Pandanus</i> spp.		Pandanaceae
<i>Psychotria mariana</i>		Rubiaceae
<i>Pemphis acidula</i>		Lythraceae
<i>Trema orientalis</i> var. <i>argentea</i>		Ulmaceae

Economic damage to vegetable crops varied from slight damage to complete losses depending upon the kind of crop and its location in relation to adequate diurnal resting places for the snails. Ripe fruits were preferred to green fruits.

#### HABITS

During the latter part of October, 1947, snails were quite active, and the presence of small snails indicated that a major egg-laying period had already been passed. Snails were more active at night although they continued to feed diurnally during overcast or rainy periods. Daytime refuges included trees,

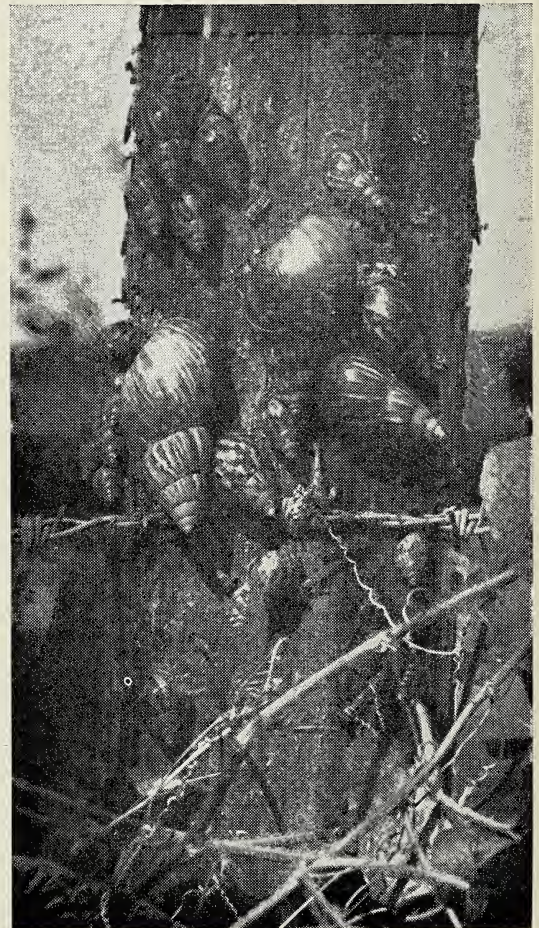


FIG. 6. *Achatina* resting on fence post, Saipan, October 19, 1947. The vine is *Passiflora foetida*, a preferred food plant.



fence posts (see Fig. 6), sides of buildings, rock piles (see Fig. 7), the under surfaces of leaves, boards, and other objects, or dense jungle growth. During favorable conditions snails crawled forth from these protected places to feed. Because of the uneven distribution of refuges, the distribution of snail populations varied and was often concentrated in certain areas. Snails often climbed up into trees to positions 10 to 25 feet above the ground and remained there during the day.

In certain areas on Saipan, Rota, and Tinian, such as plane runways, it was observed that snails often became gregarious and congregated in rather compact masses, as shown in Figure 8. It was thought that this was a method of securing protection and a mechanism of moisture conservation.

It was observed that snails were able to endure lengthy periods without feeding. One snail placed in a cardboard mailing tube lived 5 months without food, except for some of the cardboard lining. The snail died within

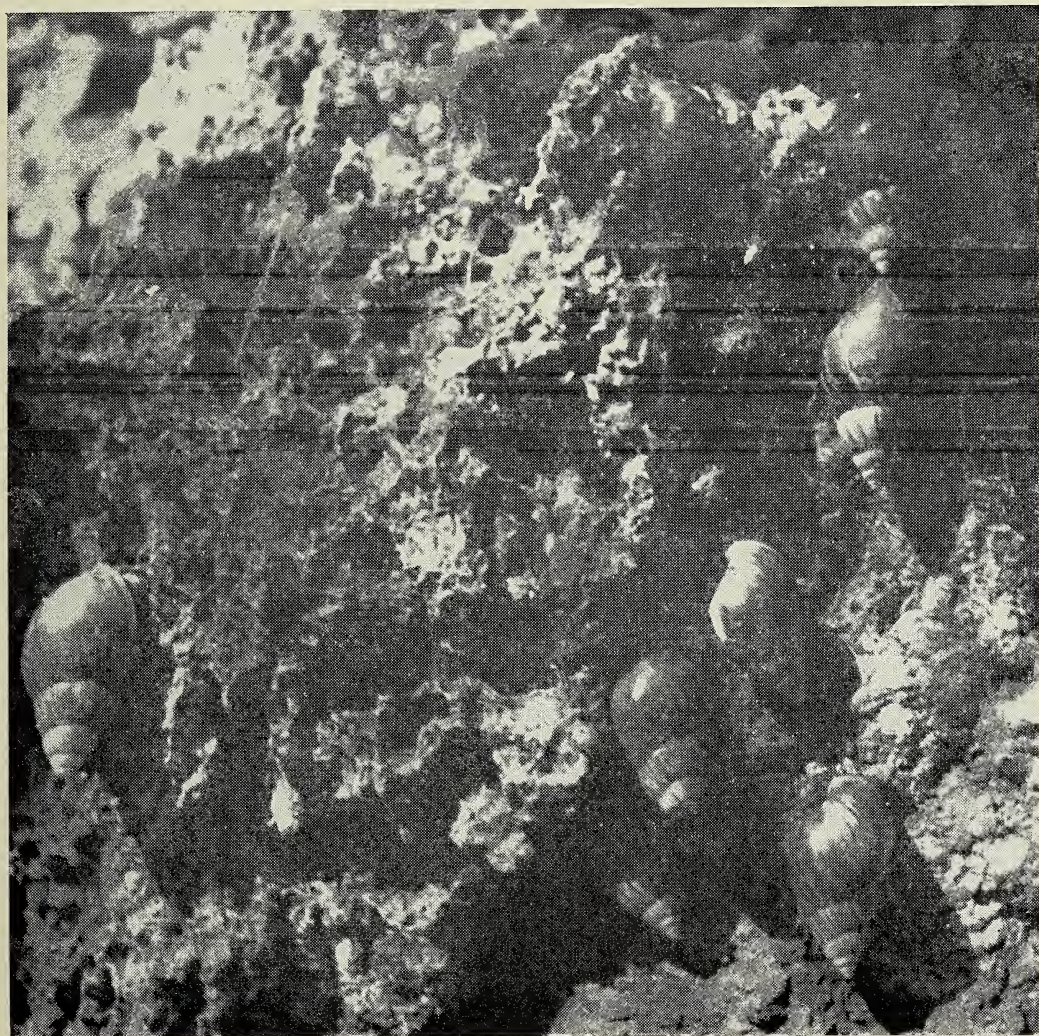


FIG. 7. *Achatina* attached to rocks during the day, Mt. Tapachou, Saipan, March 16, 1948. Note loss of apical whorls in one specimen.



a few days after it was dropped and the epiphragm broken. Another snail lived for 5½ months in an outdoor cage without food.

During unfavorable conditions snails were observed to secrete a brown calcareous epiphragm over the aperture. In the field it was noted that certain snails with epiphragms remained in an inactive condition regardless of adequate moisture. In this case it was thought that inactivity was not correlated with wet and dry conditions at the time, but with the physiological condition of the snails or status of development of the female structures.

#### NATURAL ENEMIES

A few natural enemies of *Achatina fulica* are reported in the literature. Green (1911: 43) lists enemies in Ceylon as the common pond tortoise, *Nicoria trijuga* var. *thermalis*; an ant (*Pheidologeton affinis*), which attacks

the eggs; insectivorous birds; and carnivorous beetles.

Bequaert (1925:201; also in Pilsbry, 1919:61-63) records minute, ectoparasitic mites on a living *Achatina* in the Belgian Congo and mentions the wingless flies of the genus *Wandolleckia* (family Phoridae), which live in the adult stage upon the slime of *Achatina*.

Jarrett (1931:263-264) records the Indian firefly, *Lamprophorus tenebrosus* Wlk., as an important parasite of young *Achatina fulica*.

In the Marianas no effective natural enemies of the giant snail were observed, and the toad *Bufo marinus*, supposedly introduced to feed upon snails, took no appreciable toll. On March 13, 1948, a few snails on Saipan and Tinian were found in a moribund condition although the cause of sickness was not determined. The bodies of the snails became



FIG. 8. Aggregation of *Achatina* on Tinian airstrip, March 13, 1948. Several hundred snails were found in an area of approximately 54 square inches.



lighter, receded into the shells, then became black, and finally a watery, dark-colored liquid exuded from the apertures. From dying and dead snails two species of sarcophagids were reared, namely, *Sarcophaga gressitti* Hall and Bohart and *S. dux* Thomsen (determined by C. W. Sabrosky). These flies were apparently saprophagous, being attracted to dying snails. Hall and Bohart (1948:132) report *Sarcophaga gressitti* from Saipan, Tinian, and Rota, where it was associated chiefly with filth, dead fish, dead land crabs, and snails.

During these observations there was no evidence of an epizootic among snails; rather it appeared that dying snails were stranded on roads and runways and partially desiccated before they could obtain adequate cover. This does not, however, preclude the possibility of a pathological condition among snails in other areas or under other conditions.

The presence of thin and consequently

fragile shells among snails on Saipan, Tinian, and Rota did not seem associated with a pathological condition. The possibility of genetic factors is indicated in certain Saipan localities where normal thick-shelled individuals occurred in association with thin-shelled snails. In certain cases, as on Rota (Fig. 9), the bleached shells of dead snails were found in large numbers. The reason for the death of these snails could not be determined.

#### CONTROL

The control of the giant African snail on Saipan has been approached in three ways: by chemical control, cultural control, and biological control. In certain cases it was possible to protect crops by the frequent use of pelleted baits containing metaldehyde and calcium arsenate. In areas separated from dense growth the use of a peripheral weekly treatment with pellets was found to give sat-



FIG. 9. Bleached shells of dead *Achatina* on Rota airstrip, March 16, 1948.



isfactory protection. Extensive chemical control methods in rocky or dense terrain would probably be of only temporary value unless new and more specific chemicals could be developed. The developments in new chemicals would probably have to be a divergence from related aldehydes, as was shown by the work of Lange (1941:321) in which chemicals related to metaldehyde were found to have no attraction for slugs and the European brown snail.

Cultural methods had definite value. Clearing dense underbrush near gardens or field plantings was found to be of value, as was the elimination of piles of refuse or other places where snails could hide during the day.

The work of Dr. F. X. Williams in Africa, reported by Mead (1949:41), revealed two predatory snails (*Gonaxis* sp. and *Edentulina* sp.) which may prove of value, but they require special investigation before they can be liberated. Most terrestrial predatory snails, unless they have a reproductive potential greater than *Achatina* or a decided specificity for *Achatina*, probably would not be entirely satisfactory in reducing large populations of the giant snail. This conclusion would also apply to the large predacious carabid beetle, *Tefflus* sp., found by Dr. Williams in Africa.

#### OTHER TERRESTRIAL SNAILS

In a control program it is necessary to recognize other terrestrial or fresh-water mollusks present in an area, and to know their distribution and ecological relationships. A complete survey was not made, but the following list shows present knowledge concerning these other species found in the Marianas Islands:

LOCALITY AND DATE COLLECTED	SPECIES	DETER- MINER
Magicienne Bay, March 18, 1948	<i>Lymnaea (Fossaria) ollula</i>	Abbott

Loa Loa, March 11-12, 1948	<i>Lamprocystis</i> sp.	Lange
	<i>Omphalotropis cookei</i>	Lange
	<i>Omphalotropis erosa</i>	Kondo
	<i>Omphalotropis submaritima</i>	Kondo
	<i>Pythia intermedia</i> ?	Kondo
	<i>Subulina octona</i>	Kondo
	<i>Succinea</i> sp.	Kondo
	<i>Truncatella querini</i>	Kondo
	<i>Gastrocopta lyonsiana</i>	Abbott and Kondo
	<i>Lamellaxis gracilis</i>	Abbott
Mt. Nafutan, March 12, 1948	<i>Lamprocystis misella</i>	Kondo
	<i>Omphalotropis conica</i>	Kondo
	<i>Omphalotropis cookei</i> (type locality, Abbott, 1949:263-66)	Abbott
	<i>Omphalotropis erosa</i>	Kondo
	<i>Pythia</i> sp.	Kondo
	<i>Succinea piratorum</i> ?	Kondo
	<i>Succinea</i> sp.	Kondo
	<i>Synopeas javanicum</i> ?	Kondo
	<i>Truncatella querini</i>	Kondo
	<i>Diplommatina taeneolata</i>	Abbott and Kondo
Marpi Point, March 4, 1948	<i>Georissa biangulata</i>	Abbott
	<i>Lamprocystis</i> sp.	Abbott
	<i>Nesopupa quadrasi</i>	Kondo
	<i>Omphalotropis erosa</i>	Kondo
	<i>Omphalotropis submaritima</i>	Abbott
	<i>Paludinella conica</i>	Abbott
	<i>Partula gibba</i>	Abbott and Kondo
	<i>Succinea</i> sp.	Abbott
	<i>Lamellaxis</i> sp.	Lange
	<i>Omphalotropis cookei</i>	Lange
Marpi Point, March 18, 1948	<i>Omphalotropis</i> sp.	Lange
	<i>Omphalotropis</i> sp.	Lange



Mt. Tapachou, April 2, 1948	<i>Bradybaena (Eu- lota) similis</i>	Kondo
	<i>Lamprocystis fastigata</i>	Kondo
	<i>Partula gibba</i>	Abbott
N.E. Saipan, April 2, 1948 (fresh-water spring)	<i>Lymnaea (Fossa- ria) ollula</i>	Abbott

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## Notes on Amblypygi Found in Territories Adjacent to Japan

HARUO TAKASHIMA<sup>1</sup>

THE PEDIPALPI form an order of arachnids found throughout Asia, the Australian islands, and the tropical and subtropical regions of Africa and North and South America. This order contains about 160 species, divided into 3 families and 26 genera. The majority of them are found in India, the Indo-Malayan region, Central America, and northern South America. These two major concentrations in the Old and the New Worlds appear to be the centers of dispersions for the Pedipalpi.

Some species are quite small, so small that they can hardly be seen by the naked eye. Consequently, many of them have little interest to our daily lives. However, this group is very interesting scientifically and attracts the attention of many arthropodologists.

The Amblypygi, one of the several families of the Pedipalpi, is subdivided into 3 subfamilies, 13 genera, and about 53 species which inhabit the tropical and subtropical regions of Asia, Africa, America, and some of the neighboring islands of Australia. Their appearance is somewhat grotesque, but they are harmless and not to be feared, having no poison or strong biting jaws. Amblypygi have the following diagnosis: carapace much wider than its length; edge of abdomen round with no caudal appendage; tarsi of first pair of legs extraordinarily long and slender with many joints.

Among the 13 known genera, *Charon* Karsch, 1879, alone is found in territories adjacent to Japan. It has the following diagnosis: the tibia of the pedipalps is not broadly

extended; the upper ridge of the tibia has two long spines which are almost the same length and much longer than those of the other tibia; its hand has only one long spine on each of the upper and lower ridges; there are two to four small spines on the anterior part of the long spine, and they become gradually longer near the apex. Fingers are not segmented and usually have no spines, but if they are present, only minute ones are seen at the proximal end. The corrugation on the abdomen is clearly visible at the margin of the second abdominal sternum. Of these characteristics, the most useful in distinguishing this genus from all others is the absence of joints in the fingers.

Some authors divide this genus into several species, but I consider it monotypic, with a single species known as *Charon grayi* Gervais, 1844. Furthermore, I do not think it is necessary to recognize subspecies, for variations are individual and not worthy of such recognition. I propose to call this species "Kanimushi Modoki" in Japanese.

*C. grayi* is found in the Malay Peninsula, Java, the Philippines, Botel Tobago (or Kōtōsho near Formosa), Sumbawa, Amboina, New Guinea, the Bismarks, and the Solomons and Palau (Pelew) in Micronesia; it appears rare in the Malay Peninsula, while rather common in the Philippines, Manila being its type locality.

Amblypygi were reported for the first time from Micronesia by Dr. T. Esaki (1936) who obtained a male, a female, and a juvenile on the island of Peleliu in the Palau group. Since that time this animal has been found occasionally in the Palau group—as far as I

<sup>1</sup>Yamashina's Institute for Ornithology and Zoology, Nampaidai-Machi, Shibuya, Tokyo, Japan. Manuscript received October 24, 1949.



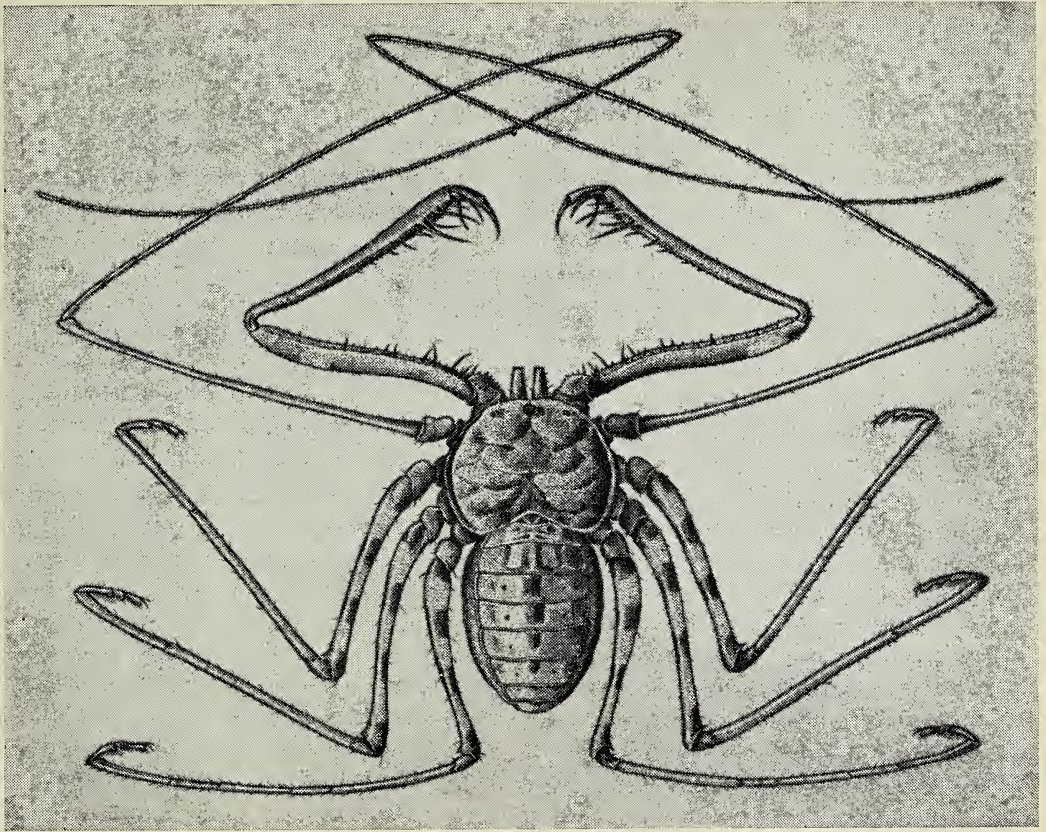


FIG. 1. Dorsal view of *Charon grayi*, female, from Botel Tobago, near Formosa. After Kano.

can ascertain, we have counted 11 examples—nevertheless it seems uncommon there. The fact that, in Micronesia, it is found only in the Palau Islands shows a close zoogeographical affinity of these islands to New Guinea and the Philippines. Fortunately I now possess 4 specimens of the 11 that have been obtained in Micronesia.

In 1936, the same year in which Dr. Esaki obtained his specimens, Dr. Kano, an able Japanese biogeographer (unfortunately missing since the war), found this species in a stalactite grotto on Botel Tobago and published an account of it in the following year. Four of his specimens were given me, and, to the best of my knowledge, these are all the Botel Tobago specimens in existence today. I am further fortunate enough to have had an opportunity to examine specimens

from Mindanao, Java, and Bougainville Island. In these various specimens, I am able to detect a secondary sexual character in this species. The femur of the pedipalp in the male is longer than the second, the third, and the fourth pairs; in the female, the femur of the pedipalp is quite similar to those of the other three. I believe this is the most easily distinguishable secondary sexual character in this species.

During the breeding season, the female of this species has an egg-sac on its abdomen. One of the two specimens which Mr. K. Sekiguchi captured on Koror in the Palaus was only 7 mm. long, which led me to believe that the one whose body measuring about 10 mm. was still in a juvenile stage. Yet I found later that it already carried an egg-sac, so I concluded that it must be an adult. This





FIG. 2. *Charon grayi* from Palau. Male, above; female with egg-sac, below. Photo by the author.

particular specimen has only seven eggs in a single layer in the sac, which measures 7 mm. across. A Javanese specimen 25.5 mm. long, in my possession, has more than 80 eggs in several layers in a sac 14 mm. long. An egg of the Javanese specimen is larger than one

of the small Micronesian adults which I have just mentioned. I consider that the diminutive adult 7 mm. long, which looks like a juvenile at first glance, is already matured, and that the animal grows to a larger size, even to the size of the Javanese specimen, as it lives and reproduces. One other specimen from Koror measured only 6 mm. long but, inasmuch as it shows the secondary sexual characters stated above, it must be concluded that it is a female.

In this present contribution I have not mentioned the body length, width of carapace, and second abdominal sternum, which also contribute to determining the secondary sexual characters of this species, but the description I have given suffices to distinguish the sexes.

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# The Subgenera of *Dubautia* (Compositae): Hawaiian Plant Studies 18<sup>1</sup>

HAROLD ST. JOHN<sup>2</sup>

## THE SUBGENERA OF *Dubautia*

THE SHRUBBY or arborescent Compositae of the Hawaiian Islands have attracted much attention and study. Among them are the related genera *Dubautia* and *Railliardia*, early described by Gaudichaud and maintained by nearly every investigator to the present. They were separated by characters of the involucre, paleae, and pappus. Many of the botanists who have done field work in Hawaii got their first concept of *Dubautia* from *D. plantaginea*, a vigorous small tree of the mountains of Oahu. Its involucre of 4 to 6 firm distinct bracts and its terminal plume of crowded oblong-ob lanceolate leaves, glabrate on the surfaces, give it a very marked habit and aspect. In *Railliardia* there are numerous species—small bushes with sessile and coriaceous, often decussate, leaves which clothe the stem for a considerable distance. The involucre is cylindric or campanulate, of several involucre bracts united into a tube. Once formed, it is difficult to break away from this concept of the two old genera, but *R. arborea* Gray and *R. struthioloides* Gray are trees; and *R. lonchophylla* Sherff, though a shrub

only 3 to 4 feet tall, has foliage similar to that of *D. plantaginea*. Thus, if all the known species are examined, it is evident that there can be no consistent groupings of the species into several genera on the basis of stature, foliage, or involucre.

In a review of *Dubautia* and *Railliardia*, Keck (1936: 24–25) emphasized the existence of species invalidating each one of the several characters alleged to separate the two genera. The two genera had recently been monographed, but Keck asserted (p. 25) that the monographer "Sherff gives an admirable systematic account of the species, but evades the question of how the two genera are to be distinguished by failing to raise it."

To one acquainted with the plants in the field there is no habitual aspect to separate the species into two groups and, as indicated, there are no strong morphological differences, not even a single constant character. Keck's merging of the two genera has not been generally adopted, inasmuch as the following botanists have continued in the maintenance of both *Dubautia* and *Railliardia*: Sherff (1941: 29–30); Degener (1940 and 1946); and Selling (1947: 330–332), who gave the first detailed account of the pollen of the Hawaiian plants. Selling accepted both *Dubautia* and *Railliardia* {=*Railliardia*}, and, referring (p. 331) to Keck's reduction, said "there seems to be no proper reason for this." Selling describes and illustrates pollen of the two genera, describing it in almost identical phrasing. He states that one cannot separate *Railliardia* from *Dubautia* on the basis of structure of the pollen grains. This might sound like a significant fact, but also inseparable on the basis of pollen structure, are the

<sup>1</sup>This is the eighteenth of a series of papers designed to present descriptions, revisions, and records of Hawaiian plants. The preceding papers have been published in *Bernice P. Bishop Mus., Occas. Papers* 10(4), 1933; 10(12), 1934; 11(14), 1935; 12(8), 1936; 14(8), 1938; 15(1), 1939; 15(2), 1939; 15(22), 1940; 15(28), 1940; 17(12), 1943; *Calif. Acad. Sci., Proc.* IV, 25(16), 1946; *Torrey Bot. Club, Bul.* 72: 22–30, 1945; *Lloydia* 7: 265–274, 1944; *Pacific Sci.* 1: 5–20, 1947; *Brittonia* 6(4): 431–449, 1949; *Gray Herb., Contrib.* 165: 39–42, pl. 3, 1947; *Pacific Sci.* 3(4): 296–301, 1949.

<sup>2</sup>Chairman, Department of Botany, University of Hawaii. Manuscript received November 22, 1949.

genera *Lagenophora*, *Tetramolopium*, *Argyroxiphium*, and other genera with the "*Dubautia* type pollen." So, at least, the pollen structure provides no significant differences between *Dubautia* and *Railliardia*. Selling twice accompanied Skottsberg on field trips to the Hawaiian Islands and Selling's rejection of Keck's work seems in harmony with that of his elder companion, Skottsberg. Skottsberg (1944: 510) discounted Keck's revision. He discussed Keck's evaluation of the characters and consequent fusing of the two genera under *Dubautia*, and said, "I cannot find, however, that he has brought to light any new circumstances, not known to Hillebrand, Sherff, Degener and other writers on this subject, and they have considered it better to keep them separate. Nothing is gained by uniting them." Then Skottsberg described a new species of *Raillardia* (= *Raillardia*). To this it may be replied that the gain attained by Keck is the delimiting of a genus with diagnostic characters that can be stated in words by one botanist and applied with the same understanding by others. The reduction of *Raillardia* to *Dubautia* is here accepted. The only recent authors accepting the view of Keck seem to be Hartt and Neal (1940: 264), Fosberg (1943: 395-397 and 1948: 115), and Neal (1948: 743). Fosberg, in his "Summary of the Hawaiian Seed Plants," places *Raillardia* as a synonym of *Dubautia* and indicates that it is a descendant of the original immigrant *Argyroxiphium*.

Of the several characters previously used for generic separation, the best and most significant are those of the freedom or union of the involucrel bracts and the degree of ciliation of the pappus. Both of these characters are significant and have always been used in the classification of these species into larger groups. However, the two pairs of characters are not always correlated. Six species have the involucre of separate bracts, and the pappus awns short ciliate lacerate or short ciliate, these representing *Dubautia* of Gaudichaud.

Twenty species have the involucrel bracts united into a campanulate or funnel-form involucre, and the pappus awns long plumose, these representing *Raillardia* of Gaudichaud. There remain three species, all from Kauai, which have the involucre campanulate, united for from  $\frac{1}{4}$  to  $\frac{3}{4}$  of its length, and the pappus awns short ciliate. These three perfectly recombine the characters of the two older groups. As they cannot be logically fitted into either of these groups, a new subgenus, *Mixta*, is made to receive them; the other two groups are described as subgenera.

Keck removes the Hawaiian genera *Dubautia* and *Raillardia* from the Madieae and, quoting Bentham's opinion, refers to their being likened to *Robinsonia* and *Rheimodendron* of Juan Fernandez. The similarity is in their habit of growth as small rosette trees, but in characters of flowers and fruit there are fundamental differences from these genera of the Senecioneae. Keck inclines towards the views of Skottsberg that close relatives are *Bedfordia* of Australia and *Brachionostylum* of New Guinea. These are both of the Senecioneae, and, on analysis of their characters, are markedly different. *Bedfordia* is a genus of two species of Tasmania and Victoria in Australia—shrubs or trees with stellate tomentose leaves, heads axillary or in axillary panicles, and the denticulate capillary pappi very numerous and caducous. *Brachionostylum* is a monotypic genus from the high mountains of southwest New Guinea—a shrub with the heads unisexual, heterogamous, anthers free, and the pappus bristles slender, capillary, roughened, and early caducous. On comparison, neither of these genera has the habit, or similarity of flower and fruit structure, to suggest that it is a close relative of *Dubautia*.

Keck agrees with the Engler and Prantl system in placing the Hawaiian *Dubautia* and its relatives in the Heliantheae-Galinsoginae; that seems the best placement at present, though by its structure and habit it is not a



close relative of the other genera currently assigned to that subtribe, and those species with a smooth receptacle wholly lacking chaff are least satisfactorily placed there. Hence, the fact that all the other genera placed there are American does not necessarily imply that *Dubautia* is of American parentage. The Galinsoginae are a group transitional to the Helenieae. The Senecioneae also has to be considered, and it is worthy of note that in the Engler and Prantl key to the Compositae the old genera *Dubautia* and *Raillardia* are included in the keys of all three of these tribes. Investigations in search of a closely related genus have been made in these three tribes, but the writer must report that he failed to find one.

#### Key to Subgenera of *Dubautia*

- Involucral bracts distinct; pappus bristles short ciliate or lacerate-ciliate . *Eudubautia*  
 Involucral bracts united for part of their length,  
     Pappus bristles long plumose . . . . .  
     . . . . . *Raillardiaster*  
     Pappus bristles short ciliate . . . *Mixta*

#### Genus DUBAUTIA Gaud.

##### Subgenus *Eudubautia* subgen. nov.

*Dubautia* Gaud., Voy. Freycinet Uranie, Bot. 469, (1826) = 1830; Atlas pl. 84, 1826.

Type species: *D. plantaginea* Gaud., l. c.

Bractae involucri liberae. Aristae pappi ciliati-laceratae vel brevis ciliati.

Bracts of the involucre distinct. Pappus bristles squamose, ciliate-lacerate, or usually short plumose.

##### Enumeration of Species

- Dubautia Knudsenii* Hbd., Fl. Haw. Is. 223, 1888.  
*D. laxa* H. & A., Bot. Beechey Voy. 87, 1832.  
*D. laevigata* Gray, Amer. Acad. Arts and Sci., Proc. 5: 135, 1861.

*D. magnifolia* Sherff, Amer. Jour. Bot. 20: 616, 1933.

*D. microcephala* Skottsbl., Hort. Gotoburg., Acta 2: 277–280, fig. 8, 1926.

*D. plantaginea* Gaud., Voy. Freycinet Uranie, Bot. 469, (1826) = 1830; Atlas pl. 84, 1826.

##### Subgenus *Raillardiaster* subgen. nov.

*Raillardia* Gaud., Voy. Freycinet Uranie, Bot. 469, (1826) = 1830; Atlas pl. 83, 1826.

Type species: *R. linearis* Gaud., l. c.

Bractae involucri cohaerentae, involucre tubulosum vel anguste campanulatum infundibuliforme est. Aristae pappi longe plumosae.

Bracts of the involucre united into an involucre tubular or narrowly campanulate or funnelform. Pappus bristles usually long plumose.

##### Enumeration of Species

*Dubautia arborea* (Gray) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.

*Raillardia arborea* Gray, Amer. Acad. Arts and Sci., Proc. 5: 134, 1861.

*D. ciliolata* (DC.) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 26, 1936.  
*Raillardia ciliolata* DC., Prodr. 6: 441, 1837.

*D. coriacea* (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.  
*Raillardia coriacea* Sherff, Bot. Gaz. 95: 80, 1933; later as *Raillardia coriacea* Sherff, Bernice P. Bishop Mus., Bul. 135: 122, 125, fig. 40, 1935.

*D. demissifolia* (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.

*Raillardia demissifolia* Sherff, Bot. Gaz. 95: 78, 1933; later as *Raillardia demissifolia* Sherff, Bernice P. Bishop Mus., Bul. 135: 118–120, fig. 38, 1935.

- D. Hillebrandi** (Mann) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936 (as *D. Hillebrandii*).  
*Raillardia Hillebrandi* Mann, Amer. Acad. Arts and Sci., Proc. 7: 175, 1867 (as *Raillardia Hillebrandii* Mann in Sherff, Bernice P. Bishop Mus., Bul. 135: 126, 1935).
- D. kohalae** (Skottsbo.) comb. nov.  
*Raillardia Kohalae* Skottsbo., Hort. Gotoburg., Acta 15: 510-511, 1944. The specific name is a geographic one, taken from the type locality in the Kohala Mts., and hence, following Rec. XLIII of the International Rules, should be written with a small initial letter.
- D. latifolia** (Gray) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 26, 1936.  
*Raillardia latifolia* Gray, Amer. Acad. Arts and Sci., Proc. 5: 132, 1861.
- D. linearis** (Gaud.) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.  
*Raillardia linearis* Gaud., Voy. Freycinet Uranie, Bot. 469, (1826) = 1830; Atlas pl. 83, 1826.
- D. lonchophylla** (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.  
*Raillardia lonchophylla* Sherff, Amer. Jour. Bot. 20: 619, 1933; later as *Raillardia lonchophylla* Sherff, Bernice P. Bishop Mus., Bul. 135: 122, fig. 39, 1935.
- D. Menziesii** (Gray) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.  
*Raillardia Menziesii* Gray, Amer. Acad. Arts and Sci., Proc. 5: 133-134, 1861.
- D. molokaiensis** (Hbd.) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.  
*Raillardia Molokaiensis* Hbd., Fl. Haw. Is., 226, 1888.
- D. montana** (Mann) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.  
*Raillardia montana* Mann, Amer. Acad. Arts and Sci., Proc. 7: 176, 1867.
- D. platyphylla** (Gray) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.  
*Raillardia platyphylla* Gray, Amer. Acad. Arts and Sci., Proc. 5: 134, 1861.
- D. reticulata** (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.  
*Raillardia reticulata* Sherff, Bot. Gaz. 95: 78, 1933; later as *Raillardia reticulata* Sherff, Bernice P. Bishop Mus., Bul. 135: 128, 130, fig. 41, 1935.
- D. Rockii** (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.  
*Raillardia rocki* Sherff, Bot. Gaz. 95: 79, 1933; later as *Raillardia Rockii* Sherff, Bernice P. Bishop Mus., Bul. 135: 130-131, 1935. The change from *R. rocki* to *R. Rockii* was made by Sherff himself in his second discussion of the species. Though he quoted the original specific name incorrectly as *Rockii*, still this second one is an acceptable form of a personal specific name, and it can be adopted as a correction by the author himself of a typographical error.
- D. scabra** (DC.) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 26, 1936.  
*Raillardia scabra* DC., Prodr. 6: 441, 1837.
- D. Sherffiana** Fosb., Torrey Bot. Club, Bul. 70: 395-397, 1943. (See fig. 1.)
- D. struthioloides** (Gray) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 28, 1936.  
*Raillardia struthioloides* Gray, Amer. Acad. Arts and Sci., Proc. 5: 134, 1861.
- D. ternifolia** (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.  
*Raillardia ternifolia* Sherff, Amer. Jour. Bot. 20: 618, 1933; later as *Raillardia ternifolia* Sherff, Bernice P. Bishop Mus., Bul. 135: 121, 1935.
- D. thyrsiflora** (Sherff) Keck, Bernice P. Bishop Mus., Occas. Papers 11(19): 27, 1936.  
*Raillardia thyrsiflora* Sherff, Amer. Jour.



Bot. 20: 618, 1933; later as *Railliardia thyrsoiflora* Sherff, Bernice P. Bishop Mus., Bul. 135: 121–122, 1935.

Omitted from this enumeration of species are numerous described varieties and forms. Also omitted are the several interspecific hybrids and intergeneric hybrids described by Sherff or by Degener and Sherff. These putative hybrids have not been evaluated and allocated by the writer.

#### Subgenus *Mixta* subgen. nov.

Type species: *Dubautia raillardioides* Hbd.; the reference follows.

Bracteae involucri plusminusve cohaerentae, involucrem campanulatum est. Aristae pappi brevi ciliati.

Bracts of the involucre more or less united; involucre campanulate; pappus bristles short ciliate.

#### Enumeration of Species

*Dubautia paleata* Gray, Amer. Acad. Arts and Sci., Proc. 5: 135, 1861.

*D. raillardioides* Hbd. (as *D. raillardiodides*), Fl. Haw. Is. 224, 1888, emend. Sherff, Bernice P. Bishop Mus., Bul. 135: 107, 1935. Hillebrand published his new species as *D. raillardiodides* and discussed its similarity to the next genus, *Raillardia* of Gaudichaud. We must accept this generic name as *Railliardia*, which was the original, well-formed, and valid name. Hence, though there is no covering rule, Sherff took the logical, and, we believe, correct course in changing the specific name to be in harmony with the correct spelling of the generic name. He was not justified in capitalizing the specific name *D. raillardioides* under the 1935 International Rules of Botany, Rec. XLIV, examples, and Art. 3.

*D. waialeale* Rock, Torrey Bot. Club, Bul. 37: 303–304, f. 5, 1910.

#### NOTES ON *Dubautia Sherffiana*

The type collection of *Dubautia Sherffiana* Fosb. is H. St. John & F. R. Fosberg 12,161, from Oahu, Waianae Mts., brushy ridge, east of 2nd gulch east of Kaupakuhale, Mokuleia, 2,500 ft. alt., Oct. 23, 1932. At the same time and locality, only 200 feet higher up the same ridge, another collection of this novelty was made (St. John & Fosberg 12,162); but this was not listed in Fosberg's paper.

The species of the subgenus *Raillardiaster* are not common on Oahu, and not until September 18, 1949, did the writer find another colony. When climbing one of the narrow rocky ridges leading to Puu Kanehoa in the Waianae Mountains, he saw below him a patch of unfamiliar yellow flowers. By grasping hands with a student he was lowered over the brink and he grabbed a few sprigs of what appeared to be *Raillardiaster*. Returning the next week, he was roped by his companions, M. Canoso and C. E. St. John, and lowered 20 feet down the vertical basalt cliff. There, on a dirt covered ledge so narrow as to deny a foothold to man, were three vigorous bushes 1–1.5 meters tall, many-branched, with the numerous cymes in full golden flower. After taking photographs and gathering full specimens, the collector was hauled again to a foothold on the knife-edged ridge. The data for these specimens are: Oahu, Waianae Mts., southeast ridge of South Peak of Puu Kanehoa, on face of basalt cliff, 20 ft. below crest of sharp ridge, 2,600 ft. alt., in open sunny spot, at top of thicket of *Metrosideros* and *Euphorbia*, Sept. 25, 1949, H. St. John 23,924; and also, 23,922 and 23,923. Though collected in the southern part of the Waianae Mountains, these specimens proved to be of the same species, *Dubautia Sherffiana* Fosberg, earlier described from the northern part of the range. After studying all of the specimens, including an isotype, the following changes in description are proposed: blades



FIG. 1. *Dubautia Sherffiana* Fosb. *a*, habit  $\times \frac{1}{2}$ ; *b*, leaf  $\times 1$ ; *c*, achene with pappus  $\times 5$ ; *d*, involucre and flowers  $\times 5$ . From *St. John* 23,924.



5(-7)-nerved; pappus bristles 16-25 in number, 2.5-3.5 mm. long.

Though the subgenus *Railliardia* is rare on Oahu, there are to be considered two published records of its occurrence. Sherff (1935: 113) summarizes the range of *Railliardia scabra* as "Hawaii, Maui, and Oahu." This species is common and Sherff lists nearly a whole page of specimens, but no collection from Oahu is in his list. None is in the Bishop Museum; nor has any other published record been seen, so Sherff's record seems to be an error.

Sherff also lists (1935: 125-126) *Raillardia linearis* Gaud. as on "eastern Maui, western Oahu, Lanai, and Hawaii." For Oahu he cites, U. S. Exploring Expedition, Kaala (Waianae) mountains, Oahu, 1840 (Gray, New York). Since 1840 no other collector has found this species on Oahu, but many have done so on the three more southerly islands. The flora of Oahu is the best known of any island in the group and its montane flora is well preserved. The U. S. Exploring Expedition also obtained specimens of this species on Maui and Hawaii. This expedition was large and well organized but inharmonious. The commander, Capt. Charles Wilkes, had trouble with his officers on the trip and after it, and with the scientists for decades afterwards while acting as editor of the publications of the expedition. In the botanical collections made by this expedition, it is now known that there is much confusion, as often the loose labels with the data were inserted with the wrong specimens. Piper (1906: 15) discussed this in detail, and the evidence is well known. It is probable that the U. S. Exploring Expedition specimen came not from Oahu, but from Maui or Hawaii with their other collections of these species. In any case, their record from Oahu is questionable until confirmed by a well-substantiated collection.

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Descriptions of Some Species of the Genus *Pulvilligera*  
Strand from the South and Southwest Pacific  
(Hymenoptera: Chalcidoidea; Torymidae)

H. E. MILLIRON<sup>1</sup>

STRAND (1911) proposed the tribe Pulvilligerini based on a new monobasic genus, *Pulvilligera*, the type of which is *P. maxima*, described by him in the same paper from six males collected by H. Sauter in 1908 at Taihanroku, Formosa. He made use of the key to the tribes of Toryminae (= Callimominae) published by Schmiedeknecht (1909), obviously without being aware of the error therein, which described the tribe Megastigmini as having one calcar on the hind tibia, instead of two that the group really possesses. If Strand had realized this fact, he would probably have placed *P. maxima* in the tribe Megastigmini, because its close affinity with the Megastigmini, except for this one character, was clearly indicated at the time he proposed the new names.

Crawford (1914) treated Pulvilligerini as a subfamily without having seen *P. maxima*. In his key, Pulvilligerinae was differentiated from Megastigminae only on the basis of "whorls of hair" on the male antennae. The identity of the Pulvilligerinae has remained completely obscured and unrecognizable for many years. Girault (1915) stated that there "is an undescribed genus in this group [Megastigmini] like *Megastigmus* but the male antennae are very slender and with whorls of hair," but he had not obtained females with certainty. In 1928 the same worker described a species which he placed in the genus *Pulvilligera*.

During 1944 a long series of specimens, part of which appear to represent the same

species described by Strand from Formosa, was collected on one of the Solomon Islands. In a recent publication by the writer (1949) the Pulvilligerinae were omitted from the key (p. 259) pending further study of *P. maxima* as well as of the two new species that are described later in this paper. This study has led to non-recognition of the name Pulvilligerini and of the subfamily name based on it. It is proposed here to treat *Pulvilligera* merely as a genus of the tribe Megastigmini.

While the male antennae of the three species at hand are distinctly different from those of any other known megastigmine species, the females are very much like those of other species of the genus *Megastigmus*. The value of this antennal character of the male as a basis for the recognition of tribal and subfamily groups is extremely doubtful because males of different species within several chalcidoid genera may exhibit striking differences in appearance of the antennae.

*Acknowledgment:* The writer gratefully acknowledges the kindness of Mr. C. F. W. Muesebeck, Chief of the Division of Insect Identification, U.S.D.A., who made it possible to study this material at the U. S. National Museum.

Tribe MEGASTIGMINI

Genus PULVILLIGERA Strand

*Pulvilligera* Strand, Ent. Rundschau 28: 59, 1911. Monobasic. Type: *P. maxima* Strand.

Species of this genus differ from those of the typical genus as follows:

<sup>1</sup>Glendale, West Virginia. Manuscript received March 31, 1950.



*Male*: Antenna slender with distinct three-segmented club bearing short, thick, almost recumbent pubescence; funicle with segments of nearly equal length, each swollen basally, less so distally, and with long, stiff, inclined or suberect pubescence, sparser than that on the club and arranged in somewhat irregular whorls (Fig. 1).

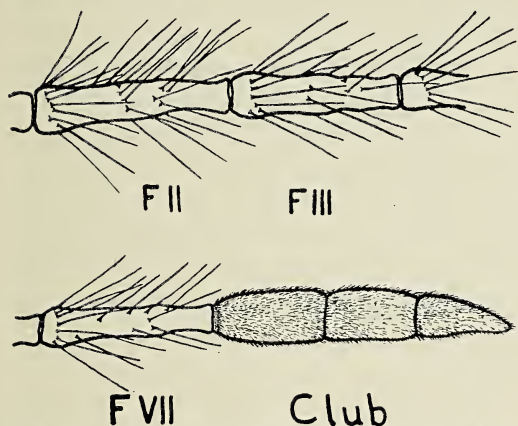


FIG. 1. Sections of typical male antenna of the genus *Pulvilligera*.

*Female*: Antenna with an indistinct three-segmented club, and all the funicular segments of about the same width.

### *Pulvilligera maxima* Strand

*Male*: Length 13.0 mm.; abdomen 5.3 mm. Outline of head from above, oval, less than twice as thick as long, depressed on vertex and along an oblique line from each lateral ocellus to each compound eye, the vertex and most of the ocellar area with fine transverse rugulae which extend down over temples, the sculpture on the front sharper and more-or-less vertical, the occipital carinae sharp and evenly arcuate above; the ocellocipital line about twice as long as either the ocellocular or posterior ocellar line; scape compressed, evenly curved, and slightly longer than combined lengths of pedicel, ring segment, and FI; pedicel wider than FI; all funicular segments several times longer than thick, slightly decreasing in length progres-

sively from FI to and including FVII; club only a little shorter than combined lengths of FVI and FVII; antennal scrobe deep but not bounded by a distinct carina above. Pronotum a little longer than wide, sides nearly smooth, above with distinct transverse rugae, the emargination on anterior margin shallow; mesonotum to transverse line with prominent transverse rugae, those on the mesopraescutum more arcuate and sharpest, behind transverse line at most only weakly sculptured to smooth; basal segment of hind tarsus slightly longer than segments 2–5 combined. Propodeum with slight median longitudinal depression and crossed by numerous irregular rugae becoming more circular on either side of depression posteriorly; abdomen subdepressed.

Color mostly brownish to greenish-yellow with black (and brown) markings. Head brownish-yellow with front below antennal bases extending onto clypeus, along fronto-genal suture, gena below, the occiput bordering foramen magnum, three circular spots on vertex (one above each compound eye, another near the occipital carina), the area surrounding the ocelli and extending to compound eye and most of the antennal scrobe dark brown to black; most of scape and pedicel brownish-yellow, remainder of antenna black. Pronotum brownish-yellow (with shade of greenish-yellow) except below at sides and three separate longitudinal stripes above (two lateral, one median) which are black, the median weaker anteriorly; mesopraescutum and each mesoscutum with longitudinal median area dark brown, the remainder greenish-yellow; outer margin of axilla suffused with brown, the inner margin greenish-yellow; parapsidal furrow black; mesoscutellum greenish-yellow with a median longitudinal somewhat diamond-shaped black spot that extends to beyond the transverse line; prepectus and mesepisternum brown, remainder of pleura mostly brownish-yellow; median piece of metanotum greenish-

yellow; legs brownish-yellow except front coxa posteriorly and hind coxa anteriorly infuscated. Propodeum greenish to brownish-yellow except for the median depression, shallow groove below propodeal spiracle, and circular depression near posterior margin which are dark brown to black; tergum III (apparent first), except yellowish spot at side and sterna, black; each of terga IV–VI inclusive bordered posteriorly by narrow amber margin and with a circular lateral black spot above, otherwise these terga are predominantly reddish-brown above and light yellow at sides; tergum VII yellow except for narrow posterior amber margin.

Pubescence on body rather fine and sparse, black on antennae and dorsal areas of body and wings, remainder pale. Wings subhyaline; with fine, short, dense vestiture along whole anterior margin of costal cell of front wing; venation rather strong, proximal two-thirds of submarginal vein with 12–13 conspicuous bristles; stigmal vein short, stigma large, quadrate, the stigmal sector short, both surrounded with narrow infuscation (Fig. 2); venation dark brown or black.

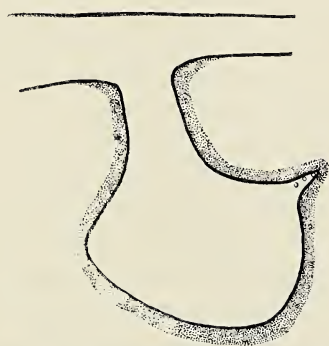


FIG. 2. Stigma of *P. maxima* male.

*Female*: Length 12.3 mm.; abdomen 5.5 mm. Ovipositor 31.5 mm. Structure of head and thorax, except for antennae and wings, much like that described for the male; scape compressed, slightly bent, about as long as pedicel, ring segment, FI, and one-half of FII combined; funicular segments subcylindrical,

decreasing slightly in length progressively in more distal segments, the proximal ones more than twice as long as thick. Propodeum only slightly depressed medially, sculptured with coarser more irregular rugae; abdomen compressed; ovipositor slender.

Head colored as in the male but less infuscated below and within antennal scrobe; antennae black except for the scape and pedicel, which are brown. Thorax colored as in the male but the median dorsal black stripe is more extensive and intensified, being weak or interrupted only on the anterior areas of both mesopraescutum and mesoscutellum; prepectus and mesepisternum lighter, and front and hind coxae without pronounced infuscation. Abdomen dark amber to brown except terga IV (apparent second) to VIII inclusive, each with yellow spot at side directed dorsad. Ovipositor sheath black.

Vestiture like that of male except proximal two-thirds of submarginal vein with about 14 conspicuous bristles, and dense vestiture present only on distal half of costal margin; wings subhyaline, venation strong, dark brown or black; stigma rather small (Fig. 3), somewhat oval, narrowly surrounded with infuscation; stigmal vein rather thick, about as long as greatest stigmal width, surrounded with narrow infuscation.

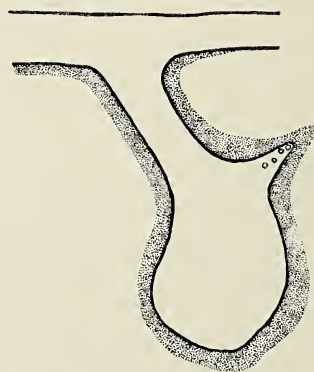


FIG. 3. Stigma of *P. maxima* female.

*Redescribed from male, reared August 30, 1944, from Pandanus seed collected at mouth*



of Evelyn River, Guadalcanal, August 23, 1944 (H. E. Milliron). Specimen in the collection of the U. S. National Museum.

**ALLOTYPE:** Female, with the same data as the male mentioned above except that it was reared August 25, 1944. Specimen in the collection of the U. S. National Museum.

**TYPE:** One of six males, probably in the Zoological Museum, Berlin, Germany. Type not examined.

**TYPE LOCALITY:** Taihanroku, Formosa.

**HOST:** Seeds of *Pandanus upoluensis* Martelli. (In the Solomon Islands.)

**DISTRIBUTION:** Formosa and Guadalcanal.

**ADDITIONAL SPECIMENS EXAMINED:** The writer also has studied a series of 86 males and 83 females, Mouth of the Evelyn River, Guadalcanal, 23 Aug. 1944, (H. E. Milliron). Ex seed of *Pandanus*. These are a part of the same lot as the above male and allotype female, and all were reared between August 23 and September 9, 1944. The *Pandanus* was later identified as *P. upoluensis*. The entire series is contained in the collection of the U. S. National Museum, 50 being preserved in alcohol.

**VARIATIONS:** *Male:* The lightest specimens are predominantly brownish- (and greenish-) yellow with reddish-brown over most of abdominal terga IV–VI inclusive, the black markings being reduced on the head to the area surrounding the ocelli and along a narrow line from the lateral ocellus to the compound eye, as well as narrowly around the foramen magnum. There is only a faint indication of the lateral spot above the eye (of the three spots on the vertex and temples). The three longitudinal stripes on the dorsum of the pronotum are reduced to separate elongate spots posteriorly, the median one being the faintest. Only an elongate black spot appears on the mesonotum, the remainder showing only faint traces of longitudinal black stripes. The propodeum is without trace of infuscation. The basal abdominal tergum (III) is blackish only at the base, and terga

IV–VI inclusive have only a slight indication of any black lateral spot above. All legs are yellowish.

The darkest male has pronounced black markings much as described but more intense and extensive. Most of the face below, except laterad of the clypeus and the area bordering the eyes in front, is very dark. The lateral spot above the eye is triangular, more enlarged, and extends down a considerable distance on the temples. The median spot extends posteriorly and unites with the black around the foramen magnum. A blackish extension appears on the front above, extending forward from the line described between the lateral ocellus and the compound eye. The lighter parts of the head are brownish to brownish-yellow. All lighter areas of the thorax are deeper than that described for the typical male, and there are three distinct dorsal longitudinal black stripes, the lateral one extending to the axilla and the median at least to the transverse line on the mesoscutellum (in some cases noticeably beyond), being only slightly interrupted at the anterior margin of the mesoscutellum. The front and hind coxae are blackish and the exterior surface of the hind femur is infuscated. The abdomen is much as described but the bands described as amber are black, and tergum VI is reddish-brown.

Between these two extremes all color gradations occur, but structurally there seems to be little variation. Larger, more robust males may be found with more distinct "verticillate" antennae and a few more conspicuous bristles on the proximal two-thirds of the submarginal vein (14–15). Males vary in size as follows: length 8.8–13.7 mm.; abdomen 3.8–5.3 mm.

*Female:* Females vary in color as do the males. The palest specimen is predominantly brownish- (or greenish-) yellow with black markings reduced on the head to the area around the ocelli and three spots on the vertex, with very little infuscation elsewhere.

The pronotum has the three separated longitudinal dorsal stripes which are weakest anteriorly. The continuation of these over the remainder of the thoracic dorsum is indicated by faint infuscation on the mesopraescutum and mesoscutum, while the mesoscutellum has a median, elongate oval blackish spot. All the legs are yellow. Only traces of infuscations are found on the propodeum and at the extreme base of the abdomen.

The darkest female has the color as described for the typical female but the scape and pedicel are dark brown to black. As with dark males, on some the black extends down onto the front from the line between the lateral ocellus and the compound eye. The lateral spot of the three on the head above is narrowly oval and on some it is extended as described for dark males. The median spot extends to unite with the black around the foramen magnum. The three black stripes on the dorsum of the thorax are very prominent and contrast with the adjacent greenish-yellow. The lateral stripe widens over the mesoscutum, becomes narrow posteriorly, and extends onto the axilla. The median stripe, which is abruptly broader at the anterior area of the mesopraescutum, becomes narrowed at the anterior margin of the mesoscutellum and extends considerably beyond the transverse line (on one specimen it extends almost the whole length). The coxae and femora and front tibia are infuscated, appearing for the most part dark brown or black. The propodeum is nearly entirely dark brown to black, and the abdomen, except for lateral yellow spots on terga IV–VIII as described, is also black.

Females vary in size as follows: length 10.0 (8 in curved position)–14.0 mm.; abdomen 4.4–6.6 mm.; ovipositor 24.0–33.0 mm.

COMMENTS: Specimens of this very variable species were all reared from seeds taken from the same *Pandanus* tree, which grew on the shore. The species is unusual in that it represents the largest species of Megastigmini

yet described. It probably occurs over most of the southwest Pacific. Females may be distinguished from those of the following new species by the more robust form, longer ovipositor, difference in appearance of the stigma, and several other characters.

*Pulvilligera neo-caledonica* n. sp.

*Female:* Length 9.5 mm.; abdomen 4.0 mm. Ovipositor 16.5 mm. Outline of head from above nearly circular but wider than long; vertex medially nearly flat, sublaterally somewhat depressed and with few shallow setigerous punctures; occipital carina sharp but not strongly developed, evenly arched except medially above; posterior ocellar line about equal to ocellocular line and both about two-thirds as long as ocelloccipital line; antennal scrobe only moderately deep and not compressed, not markedly bent, and equal to combined lengths of pedicel, ring segment, FI, and about one-fourth FII; pedicel oval, only a little wider than funicular segments, which become slightly shorter progressively from FI–FVII inclusive, and are nearly cylindrical and at least 2.5 to 3 times longer than thick; sculpture below and laterad of antennal bases strongest, consisting of irregular arcuate rugulae directed more or less obliquely from the margin of the clypeus; dorsal area of front adjacent to eye extensively reticulate, and less so below anterior to fronto-genal suture; vertex and temples weakly sculptured at most. Pronotum a little longer than wide, broadly arcuate anteriorly and with only a shallow median emargination, traversed above by regular rugulae only moderately strong; remainder of thoracic dorsum similarly sculptured except that the axilla and mesoscutellum are less noticeably rugulose to nearly smooth, especially nearly the entire surface of the latter, which shows no evidence of any external transverse line; first segment of metatarsus equal to or slightly longer than combined lengths of segments 2–4 inclusive. Propodeum somewhat ele-



vated, with irregular carinae originating along anterior margin and directed posterolaterally, median ones strongest and forming an inverted V with arcuate sides, the posterior surface less strongly sculptured with transverse arcuate carinae; abdomen compressed, smooth and polished; ovipositor sheaths slender.

Color, brown and black. Head brown, darker above, over vertex, temple, and occiput; antenna black, scape and pedicel dark brown; thorax brown, with median longitudinal stripe darker (concolorous with abdomen) and a dorso-lateral lighter and less distinct longitudinal stripe most prominent over pronotum; legs brown, the middle pair somewhat lighter. Propodeum and abdomen uniformly dark brown; ovipositor sheath black.

Vestiture mostly dark brown to black; some hairs on antenna suberect to erect, and those on thorax and abdomen somewhat longer and finer; wings nearly hyaline; venation brown, approximate distal third of costal cell of front wing with short vestiture, denser and more noticeable anteriorly along margin; proximal two-thirds of submarginal vein with 14 or 15 conspicuous bristles; stigma rather small, oval, directed toward outer wing mar-

more sharply sculptured above; scape somewhat wider and more strongly curved; pedicel oval, much narrower than scape but distinctly wider than FI; all funicular segments long and slender, each not as markedly enlarged basally (and apically), with apparently somewhat fewer hairs (than in *P. maxima*); form of thorax and propodeum similar to that of female though somewhat more sharply sculptured, and the mesoscutellum appears weakly longitudinally striate; basal segment of metatarsus slightly shorter than combined lengths of segments 2-4. Abdomen subdepressed with tergum III (apparent first), smooth, the others finely aciculate.

Color similar to that of female except the scape is brownish-yellow and the remainder of the antenna black; abdominal tergum III dark brown; sterna, and remaining terga except amber posterior margin, are lighter brown.

Body pubescence similar to that of female. Denser vestiture on anterior margin of the costal cell of the front wing does not extend quite to base of cell; proximal two-thirds of the submarginal vein with about 15 conspicuous bristles; stigmal vein very short, the somewhat quadrate stigma sessile, both bordered by an infuscated area which is most extensive below the stigma (Fig. 5).

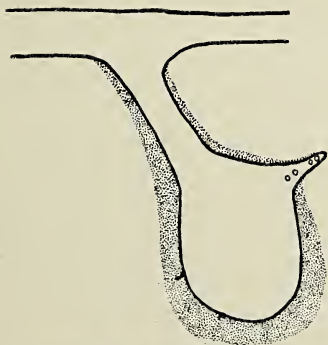


FIG. 4. Stigma of *P. neo-caledonica* female.

gin and surrounded by a narrow infuscation (Fig. 4), stigmal vein about as long as stigmal width.

*Male:* Length 9.5 mm.; abdomen 4.2 mm. Head similar to that of female, apparently

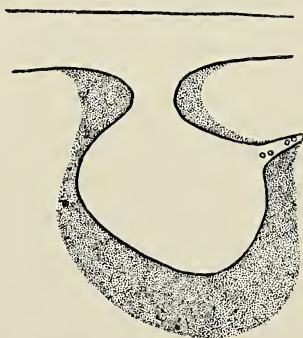


FIG. 5. Stigma of *P. neo-caledonica* male.

**TYPES:** Holotype, female, six miles east of Poindimie, New Caledonia, May 12, 1945 (H. E. Milliron). Ex *Pandanus* seed, May 20, 1945. U. S. National Museum catalogue

number 59289. Allotype, male, two paratype females, and a paratype male with the same data. All specimens are deposited in the collection of the U. S. National Museum, where is located another male (in rather poor condition, lacking both antennae beyond the pedicel) collected in Suva, Fiji, July 22, 1943, by R. A. Lever.

TYPE LOCALITY: Poindimie, New Caledonia.

HOST: *Pandanus tectorius* var. *neo-caledonicus* Martelli.

KNOWN DISTRIBUTION: New Caledonia, Fiji.

VARIATIONS: It is impossible, with so few specimens, to discuss fully the range of variation that exists in this species. Both structural and color differences are noted among the specimens at hand. The female may be slightly larger or noticeably smaller than the type, and the propodeum may be more coarsely and more irregularly sculptured. One paratype female is a little darker and the other considerably lighter, but in general the same pattern is manifested in all three females. The paratype male is slightly smaller and is paler over the lighter body regions, approaching a brownish-yellow (to somewhat greenish-yellow laterally on the mesoscutellum). The male from Fiji, aside from being considerably larger (length 11.0 mm.; abdomen 5.0 mm.), resembles the paler paratype.

COMMENTS: The specific and varietal name of the plant host, which was identified subsequently, does not appear on the labels. Although the basic thoracic color pattern of this species resembles that shown by *P. maxima* the two species are distinctly different. The shape of the stigma, weaker body sculpture, shorter basal segment of the metatarsus, and less extensive dense vestiture in the costal cell of the front wing, as well as the absence of three distinct spots on the dorsal region of the head, will serve to distinguish both sexes of this from *P. maxima*. In

addition, the females of *P. neo-caledonica* lack any distinct yellow pattern on the abdomen.

*Pulvilligera solomonensis* n. sp.

*Female*: Length 8.0 mm.; abdomen 3.5 mm. Ovipositor 17.0 mm. Outline of head from above broadly oval, about one-third wider than long; vertex nearly flat, traversed with fine rugulae barely attaining temples above; antennal scrobe moderately deep but not defined by sharp carinae dorsally; front with fine vertical rugulae which at the side converge toward the clypeus; gena and temple mostly smooth; posterior ocellar line about equal to the ocellocipital line and one-third longer than the ocellocular line; occipital carina only moderately sharp, evenly arcuate above; scape more compressed beneath (or anteriorly) and only weakly bent; pedicel elongate oval, wider than FI and about one-half as long; funicular segments cylindrical, the proximal ones being more than twice as long as thick, the distal ones (FVI and FVII) about twice as long as wide. Pronotum about as long as its greatest width, the sides slightly arcuate in outline, the dorsal area with transverse rather regular rugulae, the side nearly smooth; mesopraescutum and mesoscutum similarly sculptured, the rugulae on the anterior area of the former being more arcuate and little sharper, behind less regular and more striate; axilla with more-or-less longitudinal striations; mesoscutellum without distinct sculpture (except anteriorly), posterior half nearly smooth; basal segment of metatarsus the longest but shorter than combined lengths of remaining segments. Propodeum with short irregular carinae anteriorly, the transverse median area with prominent arcuate carina, less distinctly sculptured behind; abdomen compressed; ovipositor sheaths slender.

Color reddish-amber or brownish-orange. Head mostly brownish or dark brownish-orange, the scape and pedicel brown, remainder of antenna black. Body and legs (the



latter though somewhat paler) brownish-orange, except pale median longitudinal infuscation on mesopraescutum and mesoscutellum; base of abdomen with little brown, and somewhat deeper amber distally above, otherwise abdomen is concolorous with thorax; ovipositor sheath black.

Vestiture throughout rather sparse and fine, that on head, body above, antenna, and ovipositor sheath black, elsewhere mostly pale. Wing subhyaline, its vestiture along the anterior margin of costal cell restricted to distal half; venation brown to dark brown; stigma rather small, more-or-less oval, and narrowly surrounded by infuscation (Fig. 6), the stigmal vein about as long as the greatest stigmal width.

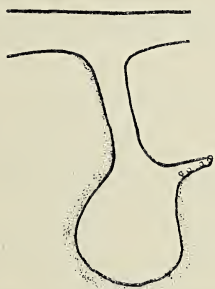


FIG. 6. Stigma of *P. solomonensis* female.

*Male*: Length 7.5 mm.; abdomen 3.5 mm. Form of head like that of the female; scape distinctly the widest segment of the antenna, compressed, and evenly curved; pedicel little wider than the base of FI; funicular segments all several times longer than wide, FI about equal to FVI, shorter than FII–V inclusive but longer than FVII, each noticeably swollen at the base but less so distally, the pubescence not dense and appearing less "verticillate" than in *P. maxima*. Sculpture of thorax and propodeum similar to that of female, the basal segments of the metatarsus distinctly shorter than the combined lengths of segments 2–5 inclusive. Abdomen depressed; tergum III (apparent first) smooth, those beyond very finely aciculate.

Color brownish-yellow and dark brown to

black. Coloration of head similar to that of the female; scape and pedicel brown, the former somewhat paler basally; remainder of antenna black. Thorax and legs brownish-yellow (or brownish-orange), dorsally with three rather distinct longitudinal brownish stripes, the median one extending over pronotum, mesopraescutum, and mesoscutellum approximately to the transverse line, and two dorso-lateral ones each extending over the pronotum and mesoscutum. Propodeum with some brownish color across the median area; abdomen dark brown to black above, median terga laterally and the sterna brownish-yellow.

Vestiture similar to that of female. Wing subhyaline, with dark brown to black venation; proximal two-thirds of submarginal vein with about 17–18 conspicuous bristles; dense vestiture along anterior margin of costal cell of front wing not extending quite to base of cell; stigma broadly oval (to subquadrate), nearly sessile, and surrounded by distinct infuscated area (Fig. 7).

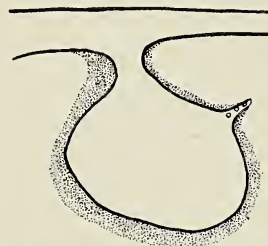


FIG. 7. Stigma of *P. solomonensis* male.

**TYPES:** Holotype, female, six miles from mouth of Tenaru River, Guadalcanal, August 13, 1944 (H. E. Milliron). Ex seed of *Pandanus*, reared August 14, 1944. U. S. National Museum catalogue number 59290. Allotype, male, with the same data. Paratypes: 44 females and 24 males, with same data as the type, all reared between August 14–25, 1944. All of these are deposited in the collection of the U. S. National Museum, as are 38 females and 6 males in alcohol, with the same data as the type except that these were reared on August 15, 1944.

TYPE LOCALITY: Mouth of Tenaru River, Guadalcanal, Solomon Islands.

HOST: *Pandanus* sp.

VARIATIONS: No significant variation in structure or color is noted among the series of females studied. Females which tend to be darkest show a pattern of brownish longitudinal stripes on the dorsum of the thorax very much like that described for the male, the median stripe being the stronger and especially conspicuous over the mesopraescutum and mesoscutellum to about the transverse line. Moreover, on such specimens usually the distal abdominal terga are darker brownish medially.

Except that the abdomen may be only subdepressed (and with some appearing as if petiolate) and the stigma may sometimes be more nearly circular, males of this species do not appear to vary significantly in structure. They do, however, show a marked range in coloration. Dark males are predominantly dark brown or black except that two dorso-lateral spots on the posterior margin of the pronotum, the inner angles of the mesoscutum and axilla, the extreme sides of the mesoscutellum, and the legs beyond the coxae are brownish-yellow. Several specimens of males lighter than these, but still darker than that described, have the anterior area of the pronotum entirely dark brown to black because of convergence of the longitudinal stripes, which are very prominent over the remainder of the thorax. The yellow on the thorax may vary from brownish-orange (or amber) to brownish-yellow.

COMMENTS: In coloration females of this species superficially resemble the North American *Megastigmus spermotrophus* Wach. All the material studied was reared from seeds taken from the same *Pandanus* tree. This species of host grows a considerable distance from the coast as isolated trees at the bottom of deep jungle ravines, and their ripe brilliant red fruit is seldom seen from the level of the jungle floor. The drupes are

similar to those of *P. motleyanus* Solms-Laub.

Females of this species may be distinguished from those of the preceding species by their distinctive color and by the shape of the stigma. Males may be recognized by the short stigmal vein, the appearance of the stigma, and by the usually depressed character of the abdomen.

#### NOTE

*P. gigantea* Gir. was described in 1928 from a female and a male taken at Townsville, Australia. It is possible that Girault's *Epimegastigmus titanus* (and *E. giganteus* referred to and compared in the description published in 1939) may belong to *Pulvilligera*. Inasmuch as no material of these species was available for study, the matter of their classification must remain unchecked temporarily.

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# Inter-tidal Ecology at Narrow Neck Reef, New Zealand (Studies in Inter-tidal Zonation 3.)<sup>1</sup>

VIVIENNE DELLOW<sup>2</sup>

## INTRODUCTION

THE PLANT and attached animal communities at Narrow Neck Reef, Auckland, have been studied in relation to factors that may be concerned with determining their vertical zonation. Observations were made between January, 1947, and July, 1948.

Certain levels on the shore appear to be more critical than others in determining the upper and lower limits of species and of communities; these levels may coincide with heights above low water at which there is a sudden change in environmental conditions. In accordance with the general aim of this series, an investigation has been made into the number and position of levels which may be critical at Narrow Neck.

*Acknowledgments:* The writer wishes to express her sincere appreciation to Professor V. J. Chapman for assistance and helpful criticism throughout this work; to Dr. G. F. Papenfuss and to Miss L. B. Moore for advice on the text; to Mr. V. W. Lindauer for assisting with the identification of Phaeophyceae and Rhodophyceae; to Mr. J. E. Morton for identification of the animals; and to Mr. L. Finch for help with the compilation of the map.

## TERMINOLOGY

While it is not proposed to enter into a lengthy discussion on the controversial topic

of marine ecological terminology, it does appear essential to state precisely the sense in which each term is employed. However, it seems unreasonable to me either to give new meanings to words now in current use in ecological nomenclature, or to impose a new series of technical terms on an already overburdened vocabulary.

As the word "littoral" has been used in so many different ways, I prefer to call that part of the shore between extreme high water mark of spring tides and extreme low water mark of spring tides the "inter-tidal region," where these extreme levels are the means of monthly extremes for the locality over a number of years. The area between Mean Extreme Low Water Spring Tide and Extraordinary Low Water Spring Tide (= Auckland Harbour Board Datum) corresponds to Stephenson's sublittoral fringe. Below this is the sublittoral or subtidal region, which is never exposed by the tide. That part of the shore from above Extreme High Water Spring Tide to the upper limit of wind-borne spray is regarded as the supralittoral, or supratidal region. It includes the somewhat arbitrary "splash" and "spray" zones, neither of which is of much importance at Narrow Neck.

Within the inter-tidal region exists a number of marine biotic communities. Some authors consider that these should be treated as though they were equivalent to terrestrial climax communities. In general, however, the marine units occupy smaller areas and may be much less long-lived, owing to the shorter life-history of the component organisms and to the super-position of the tidal factor on the climatic complex. On the other hand, because of this relative impermanence

<sup>1</sup>This paper forms part of a thesis presented for a Master of Arts degree at Auckland University College (University of New Zealand) in October, 1948. An abridged version was read before the Botany Division of the Seventh Pacific Science Congress at Auckland, in February, 1949.

<sup>2</sup>Department of Botany, Auckland University College. Manuscript received August 1, 1949.

as compared with, for example, forest vegetation, it could be maintained that the units do not justify the ecological status of a climax. In this paper, support is given to the former view; for there does appear to be a certain, fairly constant sequence of events which may be in the nature of a true succession leading up to a relatively stable climax condition. Nevertheless, more detailed work will be necessary for a satisfactory elucidation of this problem.

In assessing the ecological importance of animals in a community, one of three views may be adopted: (1) that animals are biotic factors external to the plant community; (2) that animal communities exist where plants form part of the habitat; (3) that plants and animals are interrelated, co-acting constituents of an integrated biotic community (Phillips, 1931). The third view is adopted by several authors, including Clements and Shelford (1939), who propose the biome or biotic formation as the basic unit on land or sea. The concept seems the most suitable one so far put forward for application to seashore communities and is adopted in the present work.

The broad vertical zonation in the Hauraki Gulf can be compared with that described by Stephenson (1939; 1944) for the coast of South Africa, and more recently by Dakin, Bennett, and Pope (1948) for the New South Wales coast. Four main zones can be distinguished here, of which characteristic dominants are: (1) *Melaraphe* (a littorinoid species), (2) barnacles, (3) small, turf-forming algae, and (4) large, brown algae. Each zone is regarded as constituting a separate biome, or biotic formation, since these divisions appear to be real entities of world-wide occurrence. Using Stephenson's terminology, these are equivalent to: (1) littorina zone, (2) balanoid zone, (3) mixed algal zone, and (4) sublittoral fringe.

In this paper, terms used in connection with the ecology of higher plants have been

applied to units on the seashore, according to the following definitions:

*Biome*: a biotic community with the rank of a climax formation (Clements and Shelford, 1939).

*Association-complex*: a group of associations occurring in successive belts which follow one another in a regular, constantly recurring sequence (Cranwell and Moore, 1938).

*Association*: a climax community with two or more dominants (Clements, 1916).

*Consociation*: a climax community with a single dominant (Phillips, 1931).

*Fasciation*: a portion of an association in which one or more dominants have dropped out and have been replaced by other forms, the general aspect of the community remaining unchanged (Clements, 1936).

*Clan*: a small community of subordinate importance but of distinctive character, frequently the result of vegetative propagation (Clements, 1936).

*Aspect society*: A seasonal community characterized by one or more subdominants.

*Belt*: a continuous, horizontal strip of the coast occupied throughout most of its length by one association, which may be interrupted by another community, depending on slightly local conditions (Cranwell and Moore, 1938).

*Zone*: the horizontal sector occupied by one formation and characterized by dominants of one or more associations.

#### PHYSICAL FACTORS

Narrow Neck lies about 2 miles north of Devonport, on the north shore of Waitemata Harbour, Auckland. The Harbour constitutes a ramifying arm of the Hauraki Gulf, which is almost landlocked and protected from the full force of onshore gales from the Pacific Ocean by Great Barrier and Little Barrier Islands to the north and by Coromandel Peninsula to the east. The reef itself forms part of a submarine shelf extending seawards to the Rangitoto Channel, the greatest depth of



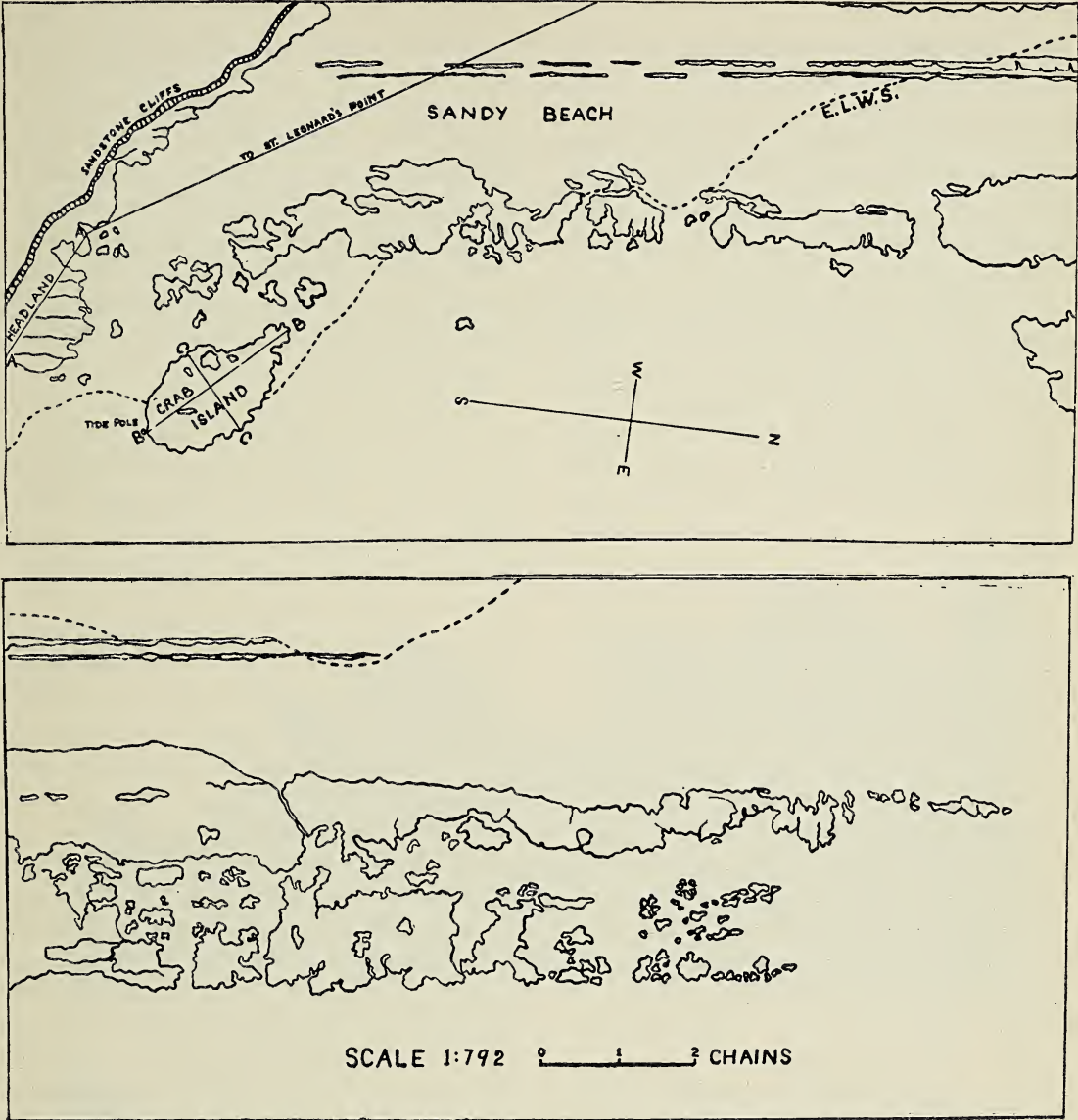


FIG. 1. Map of Narrow Neck Reef, showing position of Traverses A, B, and C. Traverse A, on Headland, top left; Traverses B and C, on Crab Island.

water at any point surrounding the reef being 2.5 fathoms. A thin layer of fine silt and mud is deposited on the gently inclined, exposed rock surface in calm weather.

There are two drainage outlets in the vicinity: one at the southern end of Narrow Neck Beach, the other at St. Leonard's Point. A considerable increase in both turbidity of water and abundance of colonial diatoms is

apparent about these places. The area studied most intensively extends from the northern end of Narrow Neck Beach to St. Leonard's Point, a distance of about five-eighths of a mile.

The reef is made up of three main groups of rock which have been named the Headland, Crab Island, and the Main Reef (see map, Fig. 1). The Headland at the cliff base

is barely covered by an extreme high spring tide. Crab Island (so-called because of the abundance of the large shore crab, *Leptograpsus variegatus*) is a small island of rock which, although slightly more elevated than the Main Reef, is covered by even the lowest high tides. At no point is the Main Reef higher than M.S.L. (6.22 feet above Auckland Harbour Board Datum).

The rock is a heterogeneous, fine, volcanic agglomerate, locally known as Parnell Grit (Bartrum and Turner, 1928). This is conformably interbedded with Waitemata Sandstone, which forms the major part of the Auckland Isthmus. There are a large number of irregular joints in the rock, along which deposition of brittle iron compounds has taken place.

The Auckland district has a maritime climate, with a relatively small daily and annual variation in temperature and precipitation (Beveridge and Chapman, 1950). Prevailing westerly winds are off-shore at Narrow Neck, and hence wave action is usually slight. Sea temperature closely follows that of the surrounding land.

There are no fresh-water outlets which would have a significant effect on the salinity of seawater in the locality. Isolated determinations were made by Hounsell (1935) at North Head, 2 miles south of Narrow Neck, and at Rangitoto Beacon to the east, where the values were 35.00 and 35.10, respectively. Both samples were collected in the morning.

The pH of seawater at Narrow Neck lies between 8.0 and 8.1, the value remaining constant throughout the year (Ambler and Chapman, in press).

Tides in the Hauraki Gulf are semi-diurnal, with an extreme spring range of about 12 feet and an extreme neap range of about 5 feet. Day and night tides differ slightly in amplitude, the night tides being greater in summer and smaller in winter. Figure 2 shows typical extreme neap and spring tides recorded for the locality by the Auckland Harbour Board. It was found from readings on a tide pole at Narrow Neck that there is no significant disparity in time and rate of tidal rise and fall in comparison with the recordings on the self-registering tide gauge at Queen's Wharf.

Tide levels were averaged from Auckland Harbour Board marigrams for the years 1945, 1946, and 1947 in order to avoid using data for 1 year only. The method of calculating the levels was that used by Beveridge (in Beveridge and Chapman, 1950). There is no significant difference between the figures for 3 years presented in Table 1 and those of Beveridge and Chapman for the year 1945. Extreme figures in Table 1 are means of monthly extremes. All heights are expressed in feet above Auckland Harbour Board Datum (0.00 feet, or Extraordinary Low Water Spring Tide).

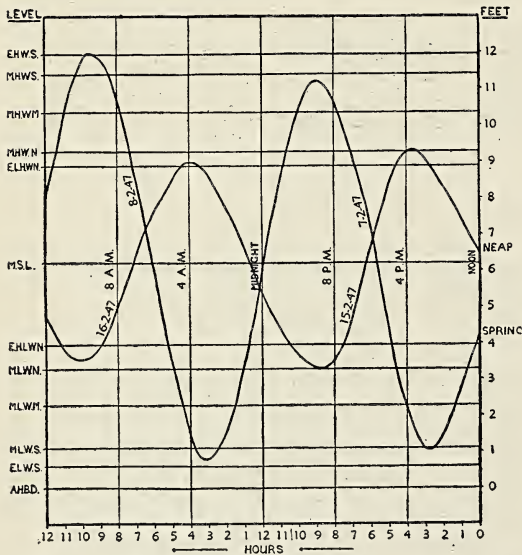


FIG. 2. Chart indicating extreme tidal ranges recorded over two 24-hour periods in the month of February, 1947, by the self-registering tide gauge at Queen's Wharf, Auckland.

TABLE 1	
TIDAL DATA FOR AUCKLAND HARBOUR	
TIDE LEVEL	HEIGHT IN FEET ABOVE A.H.B.D.
Extreme High Water Springs (E.H.W.S.)	11.95



Mean High Water Springs	
(M.H.W.S.)	11.41
Mean High Water Mark	
(M.H.W.M.)	10.35
Mean High Water Neaps	
(M.H.W.N.)	9.28
Extreme (Lowest) High Water	
Neaps (E.(L).H.W.N.)	8.88
Mean Sea Level (M.S.L.)	6.22
Extreme (Highest) Low Water	
Neaps (E.(H).L.W.N.)	3.96
Mean Low Water Neaps	
(M.L.W.N.)	3.29
Mean Low Water Mark	
(M.L.W.M.)	2.29
Mean Low Water Springs	
(M.L.W.S.)	1.12
Extreme Low Water Springs	
(E.L.W.S.)	0.60
Auckland Harbour Board Datum	
(A.H.B.D.)	0.00

LEVELING SURVEY

To obtain quantitative data concerning the levels and vertical range of the more important littoral plants and animals, a series of traverses was made in different parts of the area (see Figs. 1 and 3-6). In each case, the leveling staff was placed as near as possible to the average limit of the vertical range of the species. Elevation or depression levels due to local modifications were not taken into account. Levels of species such as *Caulerpa sedoides* and *Splachnidium rugosum* which did not occur across the paths of the traverses were obtained as isolated spot-heights from elsewhere within the area. The traverses were

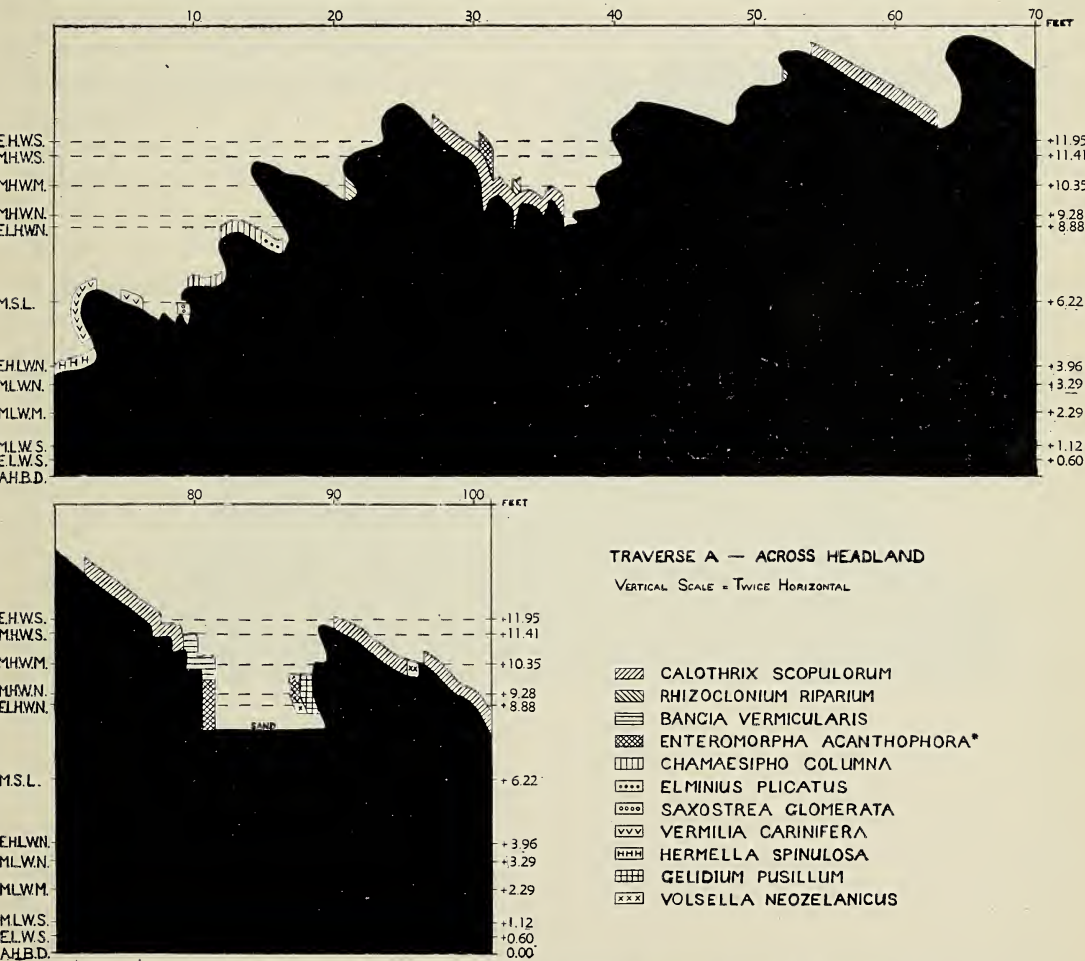


FIG. 3. Traverse A. (\* Found to be *Enteromorpha procera* f. *minuta*.)

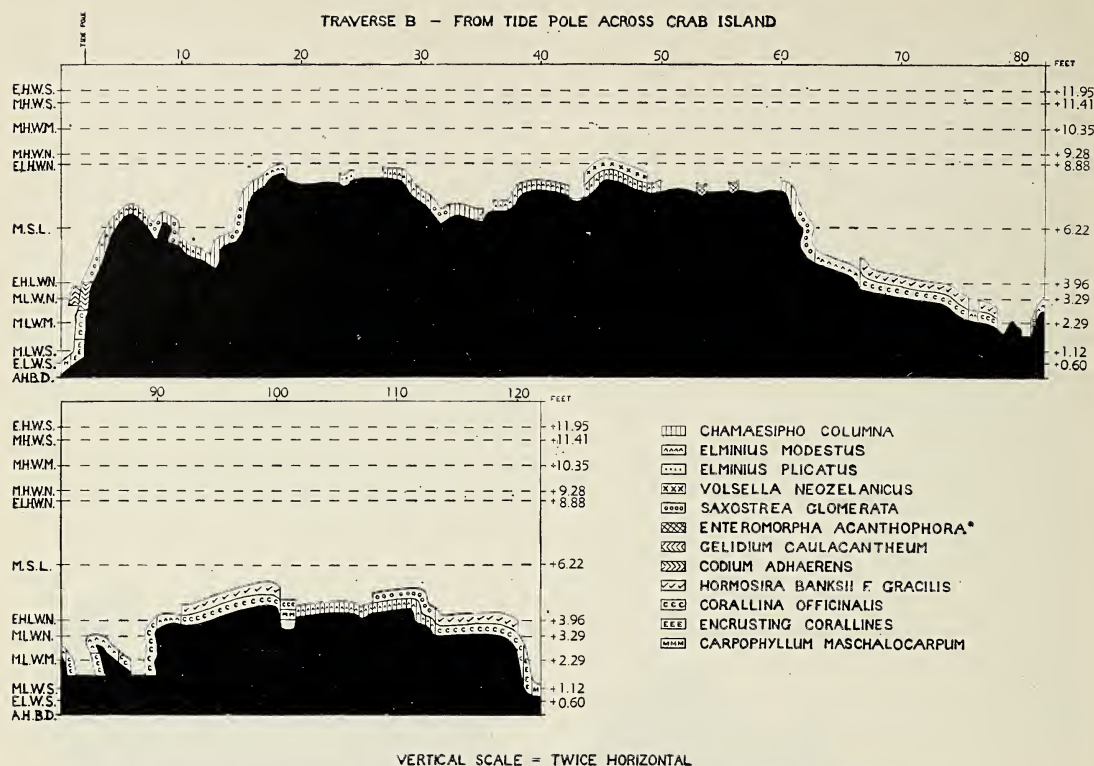


FIG. 4. Traverse B. (\* Found to be *Enteromorpha procera* f. *minuta*.)

mapped in late summer (January–February, 1948) and therefore include summer aspect societies.

*Traverse A* (Figs. 1, 3): Across Headland; length 101 feet; bearing  $116^{\circ} 20'$ .

This traverse was designed to illustrate typical zonation of the communities at higher levels. It passes from M.L.W.N.<sup>3</sup> to above E.H.W.S. and crosses in front of a small cave. The angle of dip of the rock, which is to the north, is clearly indicated. Dip faces of the inclined ledges are exposed to maximum insolation, while strike faces are shaded for most of the day. The different aspects show differences in the species colonizing the same level: for instance, near the end of the traverse, *Gelidium pusillum* and *Volsella neozelanicus* flourish on a shaded, vertical strike face at the same level as *Calothrix scopu-*

*lorum*, which usually grows above them.

In front of the cave mouth (between 80 and 90 feet) the sand level limits the downward colonization of *Enteromorpha procera* f. *minuta*.

*Traverse B* (Figs. 1, 4): Crab Island, from the tide pole across the longer axis of the island; length 122 feet; bearing  $136^{\circ} 30'$ .

In *Traverse B* the relative positions above A.H.B. Datum of the more important communities below E.(L).H.W.N. can be seen. The traverse starts at A.H.B.D., at which level *Carpophyllum maschalocarpum* is flourishing, and passes upwards successively through encrusting corallines, *Corallina officinalis*, *Gelidium caulacanthum*, oysters, and barnacles. It illustrates the wide extent of both the balanoid community at higher levels and of *Corallina* and *Hormosira* lower down on flat surfaces. The steeply ascending rock slope at the beginning of the traverse is shaded for

<sup>3</sup>See Table 1 for full explanation of abbreviations used throughout this paper.



most of the day and has a southwesterly aspect. *Codium adhaerens* flourishes here while *Hormosira* is absent. Telescoping of belts with increasing angle of slope is evident.

Traverse C (Figs. 1, 5): Crab Island, across the shorter axis, at right angles to Traverse B; length 70 feet; bearing 46° 40'.

Traverse C shows Crab Island in profile from the shore to the seaward face of the island. The change in nature and in specific composition of communities with change in level is very similar to that in Traverse B. *Enteromorpha procera* f. *minuta* and *Elminius plicatus* are poorly developed on Crab Island. It will be observed that the encrusting coralline belt descends lower than usual to seaward. *Corallina* and *Hormosira* are growing just below the 8-foot level, 4 feet above their normal upper limit, under pool conditions.

Traverse D (Figs. 6a, b): St. Leonard's Point; length 269 feet; bearing 45°.

Traverse D, the longest, runs in a direct line from high to low water. It is not shown on the map of the reef because the shape of the area as a whole is too awkward to allow the inclusion of St. Leonard's Point on a map of that scale.

The strata of the cliffs above the point are not tilted as they are at the Headland. The dip and strike of the ledges below form a correspondingly regular sequence from the cliff base to the seaward end of the point. Much of the intervening rock is flat and is covered with thick deposits of mud. The water about the point is always turbid with much suspended matter from the sewage outflow. The general zonation, however, is remarkably similar to that obtaining at Narrow Neck.

*Melaraphe oliveri* and *Calothrix scopulorum* are widespread between M.H.W.S. and E.H.W.S. Beneath the overhanging ledge 36 feet from the start of the traverse, *Ralf-*

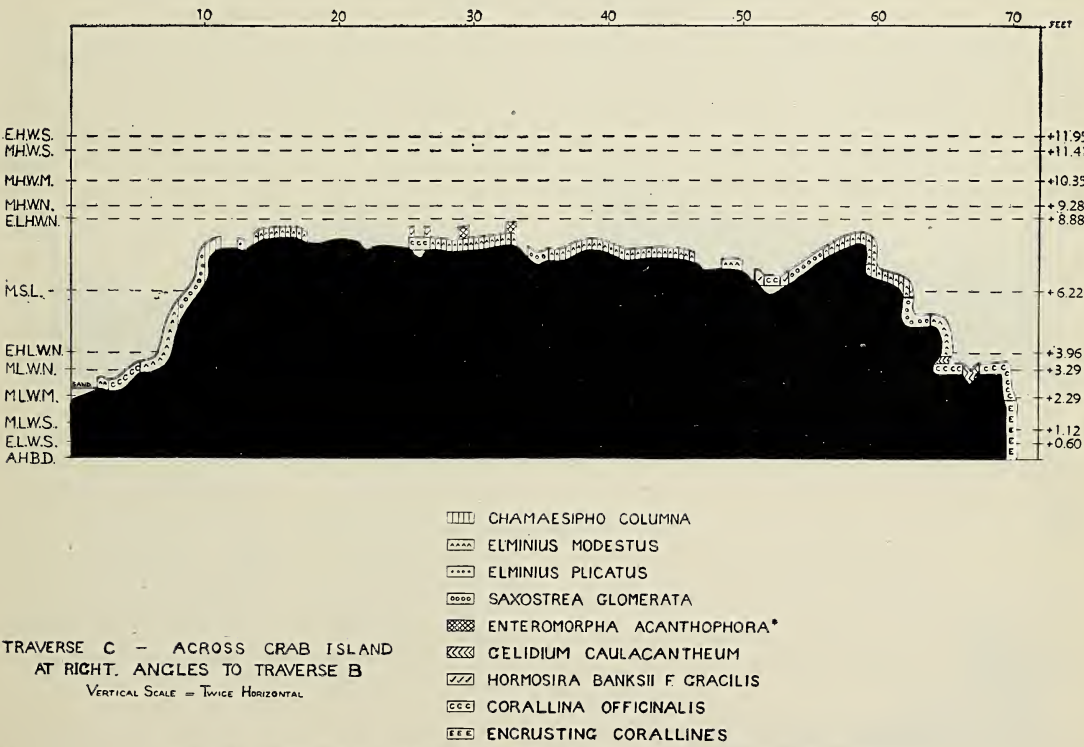
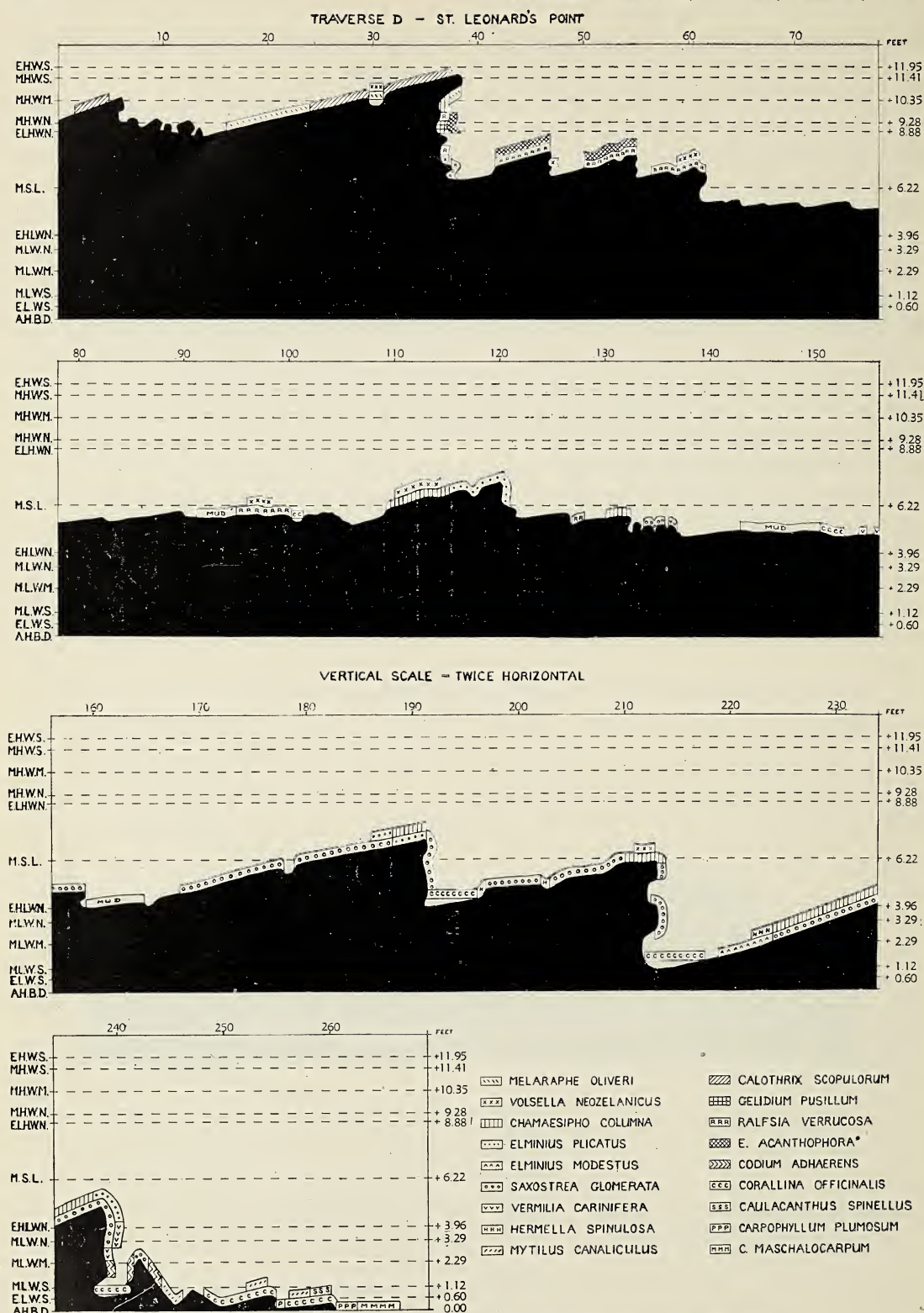


FIG. 5. Traverse C. (\* Found to be *Enteromorpha procera* f. *minuta*.)

FIG. 6. Traverse D. (\* Found to be *Enteromorpha procera* f. *minuta*.)



*sia verrucosa* and *Enteromorpha procera* f. *minuta* are growing above their normal level. Together with *Volsella neozelanicus* they colonize wide stretches of the relatively flat rock about M.S.L. Slight elevations are marked by a local increase in abundance of the large barnacle *Elminius plicatus*. The chief difference between St. Leonard's Point and Narrow Neck Reef lies in the presence of the *Mytilus*—Attached Algae Community at the former locality about E.L.W.S. (see p. 370).

From data obtained in the leveling survey, Figure 7 was constructed by plotting the vertical ranges of 25 of the more important plants and animals against the curve for the percentage of annual exposure at each level. The average amount of exposure and submergence endured by each species can therefore be calculated from this chart. (Each limit represents the average of several readings on the leveling staff.)

#### BIOTIC COMMUNITIES

These are described roughly in their order of occurrence from high to low water. It should be observed, however, that the upper limit of one association may overlap the lower limit of the one immediately above: for example, the lower limit of the *Corallina*—*Hormosira* association is given as 0.8 feet, while the upper limit of the Encrusting Coral-line association is 1.7 feet. This may be explained by local differences in such factors as topography and exposure to wave action which tend to allow the replacement of one community by another. Thus, a horizontal as well as a vertical sequence with changed conditions of habitat may be distinguished. The range of exposure undergone by each community is expressed as a percentage of the total possible exposure per annum.

#### *Littorina* Formation

##### 1. *Calothrix*—*Melaraphe* Association

Vertical range: 12.9–9.2 feet. Between E.H.W.S. and M.H.W.N.

Exposure: 100–78 per cent.

*Calothrix scopulorum* (d)<sup>4</sup>

*Rhizoclonium riparium* (ld)

*Enteromorpha procera* f. *minuta* (f)

*Microcoleus acutissimus* (o)

*Melaraphe oliveri* (d)

*Lyngbya lutea* (a)

*Lophosiphonia macra* (lf)

*Monostroma latissimum* (r)

Two separate consociations are recognizable:

##### a. *Calothrix* Consociation

The dull, blackish-green crusts of *Calothrix scopulorum* cover extensive areas of exposed rock about the highest levels of the intertidal region, especially on flat or gently sloping surfaces exposed to strong insolation. After a high spring tide or a heavy rain, the thick sheaths surrounding the trichomes become extremely gelatinous. *Calothrix* does not tolerate stagnation because in small, water-filled depressions, in which *Lophosiphonia macra* is often present, growth of *Calothrix* ceases abruptly. During periods of continuous exposure, the encrusting mat becomes dry and cracked and peels off easily. At such times the rock colonized by *Calothrix* may become white because of salt efflorescence. The upper limit of the consociation, which is much more clearly defined than the lower, is probably correlated with sudden extreme changes in salinity and microclimate. An example of sudden temperature changes in the *Calothrix* belt was recorded on February 8, 1948. At noon, rock temperature reached 33.3° C. After a brief shower it fell to 24° C.

##### b. *Melaraphe* Consociation

As *Calothrix* becomes sparser in the lower 2 feet of its vertical range, the small gastropod *Melaraphe oliveri* assumes dominance.

<sup>4</sup>d = dominant  
a = abundant  
f = frequent

o = occasional  
l = local  
r = rare

The boundaries of this community cannot be delimited precisely in terms of tide levels since *Melaraphe* is able to move within a relatively restricted area to a more favorable

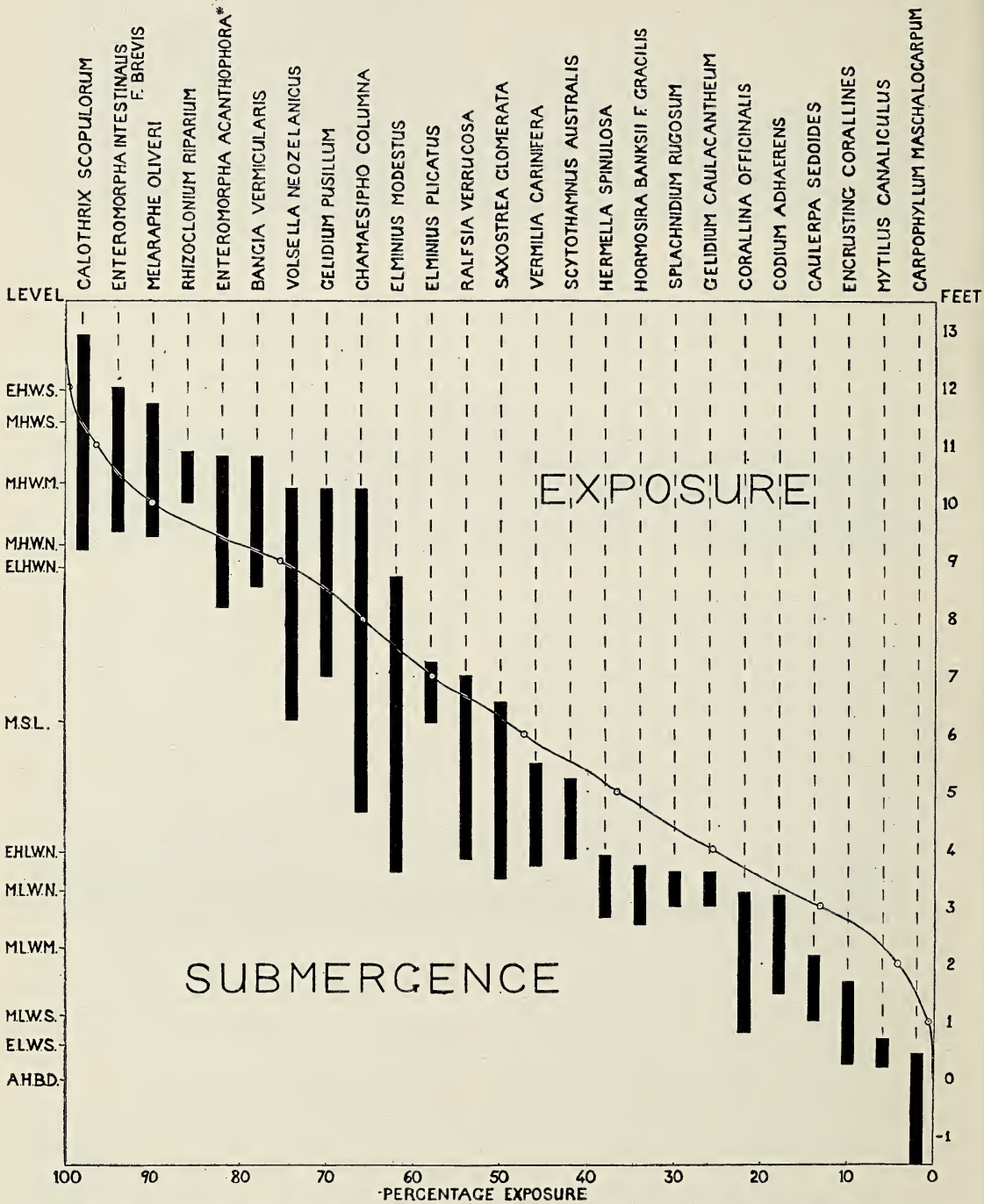


FIG. 7. The vertical range of 25 inter-tidal species (\* found to be *Enteromorpha procera* f. *minuta*) in relation to annual percentage exposure and submergence. (The limits are averaged from data obtained in the four traverses.)



local environment. During a hot summer afternoon, when the tide is low, it will migrate to a shallow pool beneath an overhanging ledge, while just after being uncovered by the tide it will present a more uniformly scattered pattern of distribution.

#### *Balanoid Formation*

### 2. *Enteromorpha* — *Gelidium* — *Volsella* (*Modiolus*) Association

Vertical range: 10.8–6.3 feet. Between M.H.W.M. and M.S.L.

Exposure: 94.7–58 per cent.

*Enteromorpha procera* f. *minuta* (d)

*Volsella* (*Modiolus*) *neozelanicus* (d)

*Chamaesipho columna* (a)

*Onchidella patelloides* (o)

*Gelidium pusillum* (d)

*Ralfsia verrucosa* (a)

*Centroceras clavulatum* (f)

*Elminius modestus* (f)

Although sometimes epiphytic on *Geli-*

*dium pusillum*, *Enteromorpha procera* f. *minuta* more often dominates in exposed situations immediately below the *Calothrix*—*Melaraphe* association. The small mussel *Volsella* (*Modiolus*) *neozelanicus* is usually entangled within the dense cushions formed by *G. pusillum*. Striking evidence of the reactions of these species to exposure and shelter is seen on the rock face south of the Headland cave (Traverse A, Fig. 3). Where the slope is vertical, with a curve that faces the incoming tide, *Enteromorpha* dominates. Where the rock is shaded or overhanging, the dominants are *Volsella* and *Gelidium*.

#### a. *Enteromorpha* Consociation

*E. procera* f. *minuta* fluctuates seasonally in abundance. Although present all the year round, it reaches maximum extent in autumn and winter, with a secondary growth period in spring. During the hottest summer months (January and February) the *Enteromorpha* community on wharf piles in the Auckland

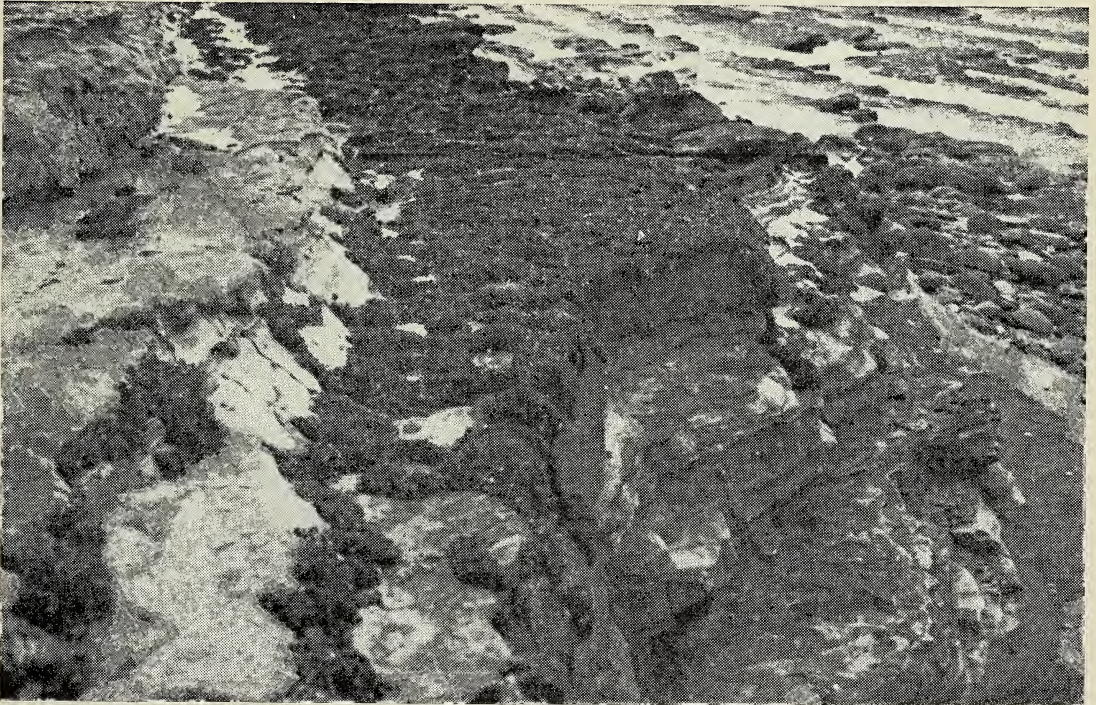


FIG. 8. *Volsella neozelanicus* consociation on a flat ledge between Narrow Neck and St. Leonard's Point.



Harbour is absent, though still growing at similar levels in the Narrow Neck locality. The mat formed by this species serves as a trap for sand and silt, which act as a moisture reservoir during periods of exposure by the tide.

b. *Volsella* Consociation (Fig. 8)

*Volsella neozelanicus* may be profoundly dominant below the level usually colonized by *Gelidium*. This suggests that the upper limit of *Volsella* is raised through association with the red alga, the thallus of which acts like a sponge in conserving moisture.

The barnacles *Chamaesipho columna* and *Elminius modestus* and the encrusting *Ralfsia verrucosa* are subordinate members of this community.

3. *Chamaesipho* — *Elminius* — *Saxostrea* Association (Fig. 11)

Vertical range: 10.2–3.6 feet. Between M.H.W.M. and M.L.W.N.

Exposure: 92–21.3 per cent.

*Chamaesipho columna* (d)  
*Saxostrea glomerata* (d)  
*Scytothamnus australis* (ld)  
*Enteromorpha procera* f. *minuta* (a)  
*Splachnidium rugosum* (f) (summer)  
*Pylaiella novae-zelandiae* (f)  
*Caulacanthus spinellus* (o)  
*Gelidium caulacanthum* (o)  
*Bangia vermicularis* (o) (winter)  
*Elminius modestus* (d)  
*Elminius plicatus* (ld)  
*Ralfsia verrucosa* (ld)  
*Volsella neozelanicus* (a)  
*Sypharochiton pellis-serpentis* (f)  
*Lepsiella scobina* (f)  
*Cellana radians* (f)  
*Cellana ornata* (o)  
*Urospora penicillaeformis* (l)  
 (autumn)

This association, which is included by Oliver (1923) in his "Shelled Animals Formation," has the widest range of distribution of any inter-tidal community in the region and

is subject to the greatest variety of changes in environmental conditions.

a. *Chamaesipho* Consociation

*Chamaesipho columna*, the smallest of the common inter-tidal barnacles, is usually to be found forming a greyish-white, horizontal belt about the mark of M.H.W.N. At this tide level the community is a closed one in places of optimum development, but towards its upper limit (M.H.W.M.) the individual barnacles are more scattered, and species from higher associations, e.g., *Volsella neozelanicus*, may become locally dominant.

b. *Elminius*—*Scytothamnus* Fasciation

*Elminius plicatus*, the largest of the inter-tidal barnacles in this locality, is locally dominant just above M.S.L., where it may form a closed community, usually not exceeding 1 foot in vertical extent. *Chamaesipho columna* and sometimes *Caulacanthus spinellus* are common epiphytes on *E. plicatus*. The dark brown fronds of *Scytothamnus australis* are the prevailing feature of portions of the community, co-dominating with either *E. plicatus* or *E. modestus*, the latter mainly at lower levels just above the coralline turf. During periods of emergence the exposed parts of the thalli become dry and parched, while portions lying directly upon the barnacles are still quite damp.

c. *Elminius modestus* Consociation

This community may be present at any level between M.S.L. and M.L.W.N. Perhaps the most striking ecological attribute of *E. modestus* is its ability to exist in muddy water. At Narrow Neck it flourishes on the gently sloping dip face of the main reef above *Coralina*, where at times there is a layer of fine silt and mud ½ inch thick. *E. modestus* is equally at home on flat, vertical, or sloping faces, whether shaded or exposed to sun, and on both upper and under sides of boulders. Once established, it can withstand relatively strong tidal currents and wave action. It is prevented from colonizing all the available rock surface within its vertical range by com-



petition, within narrower limits, from other animal communities, in particular those formed by the common rock oyster, *Saxostrea glomerata*, and by tubicolous polychaetes like *Hermella spinulosa* and *Vermilia carinifera*.

*Chamaesipho* and *E. modestus* owe their ubiquitous nature to their ability to reproduce in large numbers throughout the year (Moore, 1943) and to their wide tolerance with respect to their substrates.

d. *Saxostrea* Consociation (Fig. 9)

Vertical range: 6.5–3.5 feet. Between M.S.L. and M.L.W.N.

Exposure: 53–20 per cent.

*Saxostrea glomerata* occurs in a conspicuous belt, both upper and lower boundaries of which are sharply delimited. A species most consistent with regard to vertical range, *Saxostrea* shows relatively little variation in pattern of distribution in response to factors such as wave action, light incidence, and angle of slope of the substrate (Doty, 1946). The consociation usually gives way above

and below to a balanoid community. On the main reef, however, which is nowhere higher than 6 feet, the oyster forms the uppermost belt.

The few associated species are nearly all animals. The gastropod *Lepsiella scobina* causes much damage by boring holes with its radula through the shell of the oyster, which it extracts in pieces. Powell (1947) records that *Lepsiella* can pierce an oyster shell in 45 minutes.

4. *Hermella*—*Vermilia* Association

Vertical range: 5.5–2.8 feet. From just below M.S.L. to just above M.L.W.M.

Exposure: 42–10 per cent.

*Hermella spinulosa* (d)

*Chamaesipho columna* (a)

*Codium adhaerens* (f)

*Gelidium caulacanthum* (o)

*Vermilia carinifera* (d)

*Elminius modestus* (a)

*Centroceras clavulatum* (o)



FIG. 9. *Saxostrea glomerata* consociation on a heavily eroded ledge near St. Leonard's Point.



*Lunella smaragda* (f)  
*Neothais haustum* (o)

An association dominated by the tubicolous polychaetes *Hermella spinulosa* and *Vermilia carinifera* is characteristic of the shaded (strike) faces of ledges on Narrow Neck Beach which are adjacent to sand. *Vermilia* nearly always occurs above *Hermella*, although the two species occasionally intermix. *Hermella* appears to be more tolerant of mud. At St. Leonard's Point it reaches maximum development, forming sandy hummocks which are easily eroded by wave action and which provide a place of refuge for numerous small crabs. *Vermilia carinifera* consists of calcareous tubes attached lengthwise to the substrate. The animal occupies only the opening of the tube and protrudes when lying in a small pool, but if the shell is exposed to air it retreats within the tube, which it closes with a shelly operculum.

Subordinate species include *Codium adhaerens*, forming compact, radiating cushions on either sandy or calcareous worm tubes (Fig. 10), together with the usual barnacles and molluscs, including chitons, limpets, *Lunella smaragda*, and occasionally *Neothais haustum*.

#### Lower Mixed Algal Formation

##### 5. *Corallina*—*Hormosira* Association (Fig. 11)

Vertical range: 3.7–0.8 feet. Between E.(H).L.W.N. and M.—E. L.W.S.

Exposure: 22.2–0.5 per cent.

*Corallina officinalis* (d)  
*Colpomenia sinuosa* (a)  
*Codium adhaerens* (f)  
*Caulacanthus spinellus* (f)  
*Laurencia botrychioides* (f) (summer)  
*Laurencia thyrsoifera* (o)  
*Dictyota ocellata* (o)  
*Derbesia novae-zelandiae* (r)  
*Polysiphonia* sp. (r)  
*Chamaesiphonia columna* (f)

*Tethya fissurata* (f)  
*Hormosira banksii* f. *gracilis* (d)  
*Leathesia difformis* (a)  
*Gelidium caulacanthum* (f)  
*Enteromorpha procera* f. *novae-zelandiae* (f)  
*Splachnidium rugosum* (f) (summer)  
*Microdictyon mutabilis* (o)  
*Symphyclocladia marchantioides* (o)  
*Dasya subtilis* (r)  
*Lophurella caespitosa* (r)  
*Elminius modestus* (f)  
*Lunella smaragda* (f)

Below the level of low water neap tides, there is an abrupt change in type of community: animals become of secondary ecological importance, and algae of one kind or another are physiognomic. There is also a notable increase in the number of species and, in general, a decrease in numbers of individuals. In the relatively sheltered waters of the Hauraki Gulf the *Corallina*—*Hormosira* association is the most widely distributed algal community in the inter-tidal region. Dull reddish-brown in gross appearance, it covers all the available space on flat or gently inclined rocks between low water neap and low water spring tide levels. Although *Hormosira banksii* often dominates a separate consociation in other localities (e.g., on Takapuna Reef), at Narrow Neck it is seldom found growing apart from *Corallina*. The regular line delimiting *C. officinalis* from the balanoid association above (Fig. 11) is broken here and there by upward penetration of the *Corallina*—*Hormosira* association along cracks in the rock which serve as drainage channels.

*Hormosira* seems unable to establish itself in large numbers on vertical or steep slopes. Towards the lower limit of the association it gradually drops out, and *Corallina* assumes dominance. The latter forms a short turf of tufted plants, apparently comparable to the algal turf described by Stephenson (1939, 1944) for South Africa.



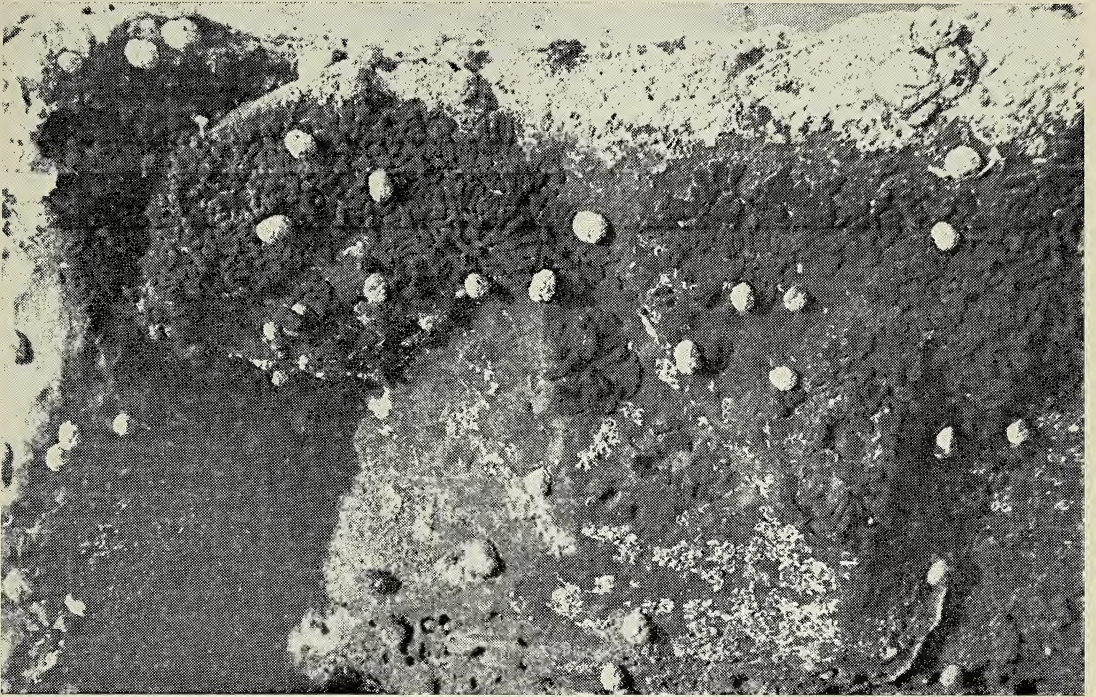


FIG. 10. *Codium adhaerens* growing above its usual level on a shaded, vertical rock face. *Chamaesipho columna* forms a white band above, *Lunella smaragda* is browsing on *Codium*, and *Vermilia carinifera* is scattered below.



FIG. 11. *Corallina*—*Hormosira* and balanoid associations on Crab Island, showing the abrupt cessation of the former with a slight increase in the level of the rock.



Nearly all of the subordinate algal species are epiphytic, chiefly because of the almost continuous covering of the substrate by the coralline turf, and most of them vary seasonally in abundance.

#### Caulerpa Clan

Within the limits of the above association, *Caulerpa sedoides* grows in isolated, cushion-like clumps between M.L.W.N. and M.L.W.S. The plant mass is so compact that other species are generally excluded, and hence the community is given the rank of clan (see p. 356).

#### 6. Encrusting Coralline Association

Vertical range: 1.7–0.2 feet. Between M.L.W.S. and 0.4 feet below E.L.W.S.

Exposure: 3–0.2 per cent.

*Corallina officinalis* (basal portion) (d)

*Peysonelia atropurpurea* (f)

*Laurencia thyrsoifera* (o)

*Elminius modestus* (o)

*Melobesia* sp. (d)

*Acrosorium decumbens* (o)

*Chamaesipho columna* (o)

On most steep rock faces which descend below low water mark, a pink band of encrusting algae separates the *Corallina*—*Hormosira* association from that dominated by species of *Carpophyllum* and *Ecklonia*. The most prevalent alga here is the basal, encrusting portion of *Corallina officinalis*. Growing with it are round or oval crusts of a species of *Melobesia*, which will readily colonize other surfaces besides rock, including shells of molluscs, and even smooth pieces of glass. Intermixed with these species is a darker red, hard crust with a slimy exterior, which appears to be *Peysonelia atropurpurea*. In shaded crevices, the delicate fronds of *Acrosorium decumbens* are sometimes to be found.

*Carpophyllum* and *Ecklonia* have their average upper limit (0.4 feet) in the Encrusting Coralline association. When growing at this level, holdfasts and stipes of the large brown algae may be exposed during a low

spring tide, but the fronds usually escape desiccation by trailing in the water below.

#### 7. *Mytilus*—Attached Algae Community

Vertical range: 0.7–0.2 feet. From E.L.W.S. to 0.4 feet below that level.

Exposure: 0.5–0.0 per cent.

*Mytilus canaliculus* (d)

*Caulacanthus spinellus* (ld)

*Elminius modestus* (a)

*Corallina officinalis* (d)

*Ulva lactuca* (l)

This community, which is of doubtful ecological status, is present locally where wave action is greater than usual for such a sheltered locality. It occurs at the extreme seaward end of St. Leonard's Point, both on the concrete sewer and on the rock ledges adjacent. During periods of exposure by the tide it is kept moist by surge from the constant swell or by spray if the wind is onshore. Under optimum conditions the principal dominant, *Mytilus canaliculus*, constitutes a closed community in which other members are forced to live as epiphytes on its shells. *Elminius modestus* is enabled to widen its vertical distribution in the inter-tidal region by colonizing the mussel shells.

*Mytilus* dominates in one other area—in a group of rocks outcropping from the submarine continuation of Narrow Neck Reef about 500 yards from the shore and 300 yards from the end of the Main Reef. Even on a calm day there is a considerable swell round these rocks. Associated with *Mytilus* here are dense clumps of *Ulva lactuca*, which does not occur on the Main Reef.

#### Sublittoral Brown Kelp Formation

#### 8. *Carpophyllum*—*Ecklonia* Association

Vertical range: 0.4 feet—. From E.L.W.S. to below the reach of all tides.

Exposure: 0.3–0.0 per cent.

*Carpophyllum maschalocarpum* (d)

*Carpophyllum plumosum* (d)

*Ecklonia radiata* (d)



*Carpophyllum flexuosum* (d)  
*Sargassum undulatum* (f)  
*Sargassum sinclairii* (f)  
*Cystophora torulosa* (f)  
*Ectocarpus indicus* (f) (summer)  
*Glossophora kunthii* (la) (summer)  
*Pterocladia lucida* (l)  
*Myriogramme gattyana* (l)  
*Zonaria subarticulata* (o)  
*Cystophora retroflexa* (o)  
*Cladhymania oblongifolia* (o)  
*Acrosorium decumbens* (o)  
*Schizymenia novae-zelandiae* (r)  
*Grateloupia polymorpha* (r)  
*Myriogramme oviformis* (f) (summer)

The present account is intended to deal only with communities of the inter-tidal region; but since the dominant species in the sublittoral fringe (i.e., between 0.6 and 0.0 feet) include those of the *Carpophyllum*—*Ecklonia* association, it will be discussed here.

An association in the sublittoral region dominated by one or more species of *Carpophyllum* is characteristic of rocky districts of the east coast of New Zealand (Oliver, 1923). Narrow Neck is no exception. The only New Zealand species not present is *C. elongatum*, the chief ecological requirement of which is deep, transparent water (Cranwell and Moore, 1938). At Narrow Neck, *Carpophyllum* and *Ecklonia* are present almost everywhere within their bathymetric limits. *C. plumosum* dominates in shallower and more sheltered habitats, and is especially common on the protected western fringe of the Main Reef (Fig. 1). *C. maschalocarpum* is by far the most abundant of the three species of *Carpophyllum* in the locality. It extends almost continuously from the base of the tide pole on Crab Island, round the seaward face of the latter, and along both sides of the Main Reef (Fig. 1). In the shallower channel between reef and shore *C. plumosum* and *Ecklonia radiata* are more physiognomic. The latter is equally abundant on both eastern and western fringes of the reef. In general,

*C. flexuosum* is more typical of deeper water than *C. maschalocarpum* and *C. plumosum*, though all three flourish about A.H.B. Datum.

The upper limit of the association is remarkably constant. There appears to be a gradation in length of thallus which increases with depth at which the holdfasts are attached. This may be a response of the individual plants in connection with the optimum depth of water for photosynthesis.

A heavy epiphytic flora and fauna is supported by mature thalli of the large brown algae, and is composed mainly of diatoms, hydroids, and delicate red algae such as *Myriogramme oviformis* and *Acrosorium decumbens*. The abundance of diatoms is enhanced by the relatively slack tidal currents and the prevailing turbidity of the water.

#### Seasonal Communities

*Porphyra umbilicalis* and *Bangia vermicularis* form a winter aspect society on exposed ledges between M.H.W.N. and M.H. W.S. *Bangia* usually persists until summer.

About the level of M.L.W.N., spring and summer communities of *Myriogloia lindauerii* and *Helminthocladia australis* may be found. Both species are influenced adversely by sand.

Towards the lower limit of the balanoid association, *Splachnidium rugosum* grows in dense or isolated patches in late summer and autumn, dying away with the onset of winter.

Seasonal species do not, as a rule, reappear the following year in exactly the same situation as in the previous one.

Several points which require further commentary arise out of this discussion of the different associations:

1. The upper and lower limits given in feet represent the average for each association concerned, and do not imply that the dominant species cannot live at other levels. For instance, the lower limit of the balanoid association is 3.6

feet, but both *Chamaesipho columna* and *Elminius modestus* occur in the Encrusting Coralline association, 2 feet below.

2. Cranwell and Moore (1938) list *Lichina pygmaea* and *Melaraphe oliveri* as the chief dominants in the "supra-littoral" or "splash zone" at Narrow Neck. However, *Lichina* does not exist as a dominant here, and it has been shown from the leveling survey that *Melaraphe* does not normally occur above E.H.W.S.
3. The same association-complex is to be found with only slight local modifications farther north on Takapuna and Milford Reefs where the substrate is volcanic basalt.

#### CRITICAL LEVELS

Inasmuch as the inter-tidal region may be divided into a number of zones, each characterized by certain species which are absent or insignificant in other zones, it may be assumed that some levels are more important than others in restricting the upward or downward extension of a species. Colman (1933), David (1943), Chapman (1943), and Evans (1947) have investigated the problem of critical levels<sup>5</sup> in Great Britain, and Doty (1946) has made similar studies on the Pacific coast of North America. The fact that David found only one such level at Aberystwyth identical with one of Colman's levels at Wembury Bay, namely E.(L).H.W.N., indicates that each locality should be treated on its own merits. Both the number and the position of critical levels appear to vary from coast to coast.

From an examination of Figure 7, it is apparent that there are certain relationships between the total number of species, the num-

ber of upper and lower limits, and the level on the shore. For example, six species have their lower limits and eight species have their upper limits of vertical distribution between the levels of 9 and 12 feet, making a total of 14 limits, while only nine species occur *between* those levels. Between 5 and 8 feet, on the other hand, there is a total of eight limits, with the occurrence of nine species. The concept of critical levels is based on the assumption that the fewer the number of species and the greater the number of upper and lower limits at a certain level, the more critical it will be in limiting the vertical range of a species or community.

The relationship between height on the shore, number of species, and number of upper and lower limits of species was investigated from data obtained in the leveling survey. Colman's (1933) method for finding critical levels was followed. By taking from Figure 7 the number of species with limits between -1 and +2 feet, 0 and +3 feet, +1 and +4 feet, and so on, three curves were constructed (Table 2 and Fig. 12).

TABLE 2  
RELATIONSHIP OF HEIGHT ON SHORE  
AND SPECIES

FEET ABOVE OR BELOW A.H.B.D.	LOWER LIMITS	UPPER LIMITS	TOTAL LIMITS	TOTAL SPECIES	DIFFER- ENCE BETWEEN TOTAL SPECIES AND TOTAL LIMITS
+12 - +15	0	1	1	1	0
11 - 14	0	3	3	3	0
10 - 13	1	9	10	9	1
9 - 12	6	8	14	9	5
8 - 11	6	7	13	10	3
7 - 10	7	3	10	10	0
6 - 9	5	4	9	9	0
5 - 8	3	5	8	9	-1
4 - 7	4	3	7	8	1
3 - 6	6	8	14	12	2
2 - 5	10	7	17	13	4
+1 - +4	11	8	19	13	6
0 - +3	9	4	13	8	5
-1 - +2	5	3	8	6	2

<sup>5</sup>A critical level may be defined as a level at which a relatively great number of species reach the upper or lower limit of their vertical ranges.

In Figure 12, curve A represents the number of lower limits at each level, curve B the



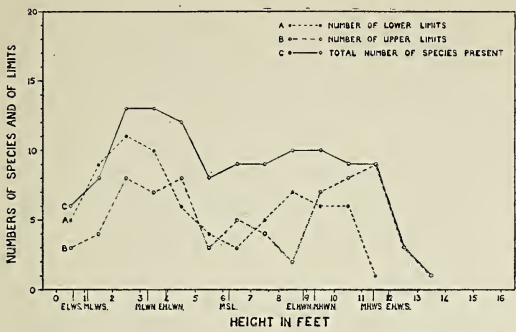


FIG. 12. Graph indicating the relationships between the number of species, and of upper and lower limits at different heights on the shore.

number of upper limits, and curve C the total number of species. There are two maxima in both A and B, one low down on the shore, and one higher up. The greatest number of both upper and lower limits occurs between +1 and +4 feet, i.e., between M.L.W.N. and M.L.W.S. (= M.L.W.M.). Curve A (lower limits) has a second pronounced maximum between 7 and 10 feet, just below E. (L).H.W.N. Curve B (upper limits) rises to a peak between 10 and 13 feet, i.e., at M.H.W.S. There is a secondary maximum at E. (H).L.W.N.

In all cases but one (between 5 and 8 feet), the total number of species is less than the total number of limits at any one level. At both Wembury and Cardigan Bays, however, the total number of species at each level always exceeded the total number of limits: that is, inter-tidal species in these localities have, in general, a wider vertical range than those at Narrow Neck. This difference may prove to be correlated with lower average minimum temperatures in Great Britain, associated with higher latitudes.

A further graph was constructed by plotting total limits minus total number of species against height on the shore (Fig. 13). Again there were two maxima—at M.L.W.M. and M.H.W.M.—with a subsidiary maximum between M.L.W.S. and E.L.W.S.

It is possible that these levels may be of critical significance in determining vertical

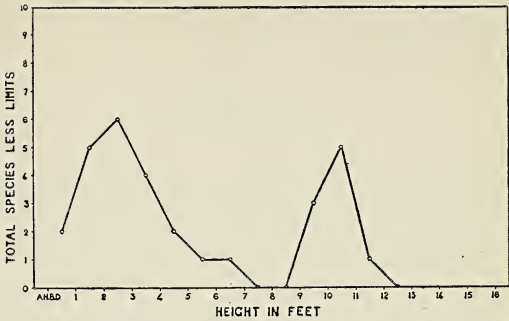


FIG. 13. Graph obtained by plotting the number of species minus the number of limits against height on the shore. The two peaks indicate the positions of two critical levels (M.L.W.M. and M.H.W.M.). M.-E.L.W.S. (between 1 and 2 feet) may also be critical.

zonation at Narrow Neck. Presumably, immediately above or below each critical level, there is a change in one or several of the factors comprising the external environment. This change must be of sufficient magnitude to restrict or inhibit optimum growth of the individuals concerned and involves a consideration of the nature of factors operating in the inter-tidal region. Investigations on the ecological factors are being continued, and it is hoped that further results will be published at a later date.

SUMMARY

An account is given of the plant and animal communities at Narrow Neck Reef, Auckland, in relation to their levels on the shore and to the range of exposure annually undergone by each. Four leveling traverses were made in different parts of the area to illustrate the main patterns of zonation.

The problem of critical levels is discussed. The following levels may be regarded as critical in determining zonation at Narrow Neck:

TIDE LEVEL	NUMBER OF SPECIES	NUMBER OF LIMITS	EXPOSURE per cent
I. M.L.W.S.—E.L.W.S.	8	13	1
II. M.L.W.M.	12	19	6
III. M.H.W.M.	9	14	92

The least critical level is 8.0 feet, nearly 1 foot below E.(L).H.W.N.

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# NOTE S

## Translations of Japanese Botanical Papers

In the course of an investigation of the vegetation of Micronesia it became necessary to have translated a number of papers published in Japanese. To save unnecessary repetition of this work by other investigators, carbon copies of these translations, eighteen in number, have been deposited in the library of the U. S. Department of Agriculture and the Library of Congress, Washington, D. C., and in the Bishop Museum Library, Honolulu. The accompanying list gives the English transliterations of the authors' names, English translations of the titles, and the references to the periodicals in which they were published.

The translations were done under my direction by Mr. G. Luhrs Stroud, of Arlington, Va. In the especially difficult article on *Digitaria* by Tuyama, the drafts were submitted to Mrs. Agnes Chase and Mr. Jason Swallen, of the Division of Agrostology of the U. S. National Herbarium, for scrutiny and correction.

HOSOKAWA, T. [*Casuarina equisetifolia* in the Marianas]. *Kudoa* 2(3): 107-113, 1934.

—— Preliminary account of the vegetation of the Marianas. *Bulletin, Biogeographical Society of Japan* 5(2): 124-172, 1934.

—— [Materials for a flora of Ponape, South Sea Islands]. *Kudoa* 3(4): 162-166, 1935.

—— [Phytogeographical considerations on the Marianas]. *Nippon Gakuzyutu Kyokai Hokoku* 10 (1) 3A: 146-151, 1935.

KANEHIRA, R. [Forests of the South Seas Occupied Islands]. *Formosan Agricultural Review (Taiwan Nobizo)* 103: 17-21 (713-717), 1915.

—— [Forests and plants of the South Sea Is-

lands]. *Dainippon Sanrin Kaiho* 394: 18-32, 1915; 395: 1-17, 1915; 401: 54-61, 1916.

—— [A botanical excursion to the northern Marianas Islands]. *Botany and Zoology (Syokubutu oyobi Dobutu)* 2(5): 913-922, 1934.

—— [Forests of Rota]. *Botany and Zoology (Syokubutu oyobi Dobutu)* 4(1): 63-70, 1936.

—— On the Micronesian *Pandanus*. *Journal of Japanese Botany* 12(8): 545-554, 1936.

—— *Palmae Micronesicae*. *Journal of Japanese Botany* 12(9): 634-640, 1936; 12(10): 729-734, 1936.

KARIYONE, T. The mangroves in the South Sea Islands. *Journal of Japanese Botany* 4(6): 116-120, 1927.

KITAMURA, S. Compositae of Micronesia. *Acta Phytotaxonomica et Geobotanica* 10(1): 70-74, 1941.

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—— [On genus *Haloragis* and Micronesian species]. *Journal of Japanese Botany* 16(5): 273-285, 1940.

—— [A plant naturalized in the South Seas]. *Journal of Japanese Botany* 18(2): 90, 1942.

—— [Notes on Japanese *Digitaria*]. *Journal of Japanese Botany* 18(1): 6-21, 1942.

—— "Rumphius' *Arbor ovigera*" and the related species with reference to *Hernandia sonora*. *Bulletin, Sigenkagaku Kenkyusyo* 1(1): 27-44, 1943.

Photographic copies of these translations may be secured from either the Library of Congress or from the library of the U. S. Department of Agriculture at a nominal cost.—F. R. Fosberg, *Pacific Vegetation Project, Catholic University of America*.

## News Notes

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, Tokyo, Japan, have been received. Each report includes a list of all the reports previously published, their distribution, and rules for obtaining them.

*Newsprint in Japan.* [By Harold R. Muddock.] Report No. 124. 31 pp., 9 figs., 12 tables.

*Japanese Whaling Industry Prior to 1946.* [By William M. Terry.] Report No. 126. 47 pp., 18 figs., 19 tables.

*Japanese Land Reform Program.* [By Laurence I. Hewes, Jr.] Report No. 127. 118 pp., 7 figs., 12 tables.

*Gold and Silver in Japan.* [By Robert Y. Grant.] Report No. 128. 112 pp., 13 figs., 1 pl., 61 tables.

*Japanese Fur Sealing.* [By Oliver L. Austin, Jr., and Ford Wilke.] Report No. 129. 91 pp., 15 figs., 4 appendices.

*Fire Clay Resources of Japan.* [By Donald E. Lee.] Report No. 130. 61 pp., 20 figs., 19 tables.

*Glossary of Japanese Forestry Terms.* [By T. Sasaki and K. Watanabe.] Report No. 131. 132 pp.

*Coal Fields of Western Honshu, Japan.* [By Robert D. MacAfee.] Report No. 132. 50 pp., 25 figs., 2 maps, 11 tables.

*Coal Fields of Hokkaido, Japan.* [By John B. Lewis.] Report No. 133. 54 pp., 25 figs., 32 tables.

*Oyster Culture in Japan.* [By A. R. Cahn.] Report No. 134. 80 pp., 40 figs., 17 tables.

In accordance with a recommendation of the Seventh Pacific Science Congress, a Conservation Council for Hawaii was organized at meetings held in Honolulu on July 18 and August 9, 1950. Members of the Council include representatives of approximately 25 Federal, Territorial, City-County, and private agencies and organizations. L. D. Baver, Director of the Experiment Station, Hawaiian Sugar Planters' Association, was elected pre-

sident; H. A. Wadsworth, Dean of the College of Agriculture, University of Hawaii, vice-president; and Paul Porter, President of the Hawaii Audubon Society, secretary. The Council will operate at present through six subject committees and chairmen as follows: Land, H. A. Wadsworth; Water, C. K. Wentworth; Plants, Colin G. Lennox; Animals, Vernon E. Brock; the Sea, Col. Rollie N. Blancett; and Sites (monuments, relics, etc.), Alice Spaulding Bowen.

*The Australian Journal of Marine and Freshwater Research* has been established by the Australian Commonwealth Scientific and Industrial Research Organization, 314 Albert Street, East Melbourne, for the publication of results of original investigations on sea, estuarine, and freshwater fisheries and related subjects. The first number has already appeared, and, if sufficient material is offered, the *Journal* will be published biannually. (From the Information Bulletin of the Secretariat of the Pacific Science Association.)

*The Prevention of Deterioration Abstracts*, published by the National Research Council (Prevention of Deterioration Center, Room 204), 2101 Constitution Avenue, Washington 25, D. C., are offered for subscription on a yearly basis. Abstracts are classified under the headings: biological agents; electrical and electronic equipment; fungicides and other toxic compounds; lacquers, paints, and varnishes; leather; lubricants; metals; miscellaneous; optical instruments and photographic equipment; packaging and storage; plastics, resins, rubbers, and waxes; textiles and cordage; and wood and paper. One volume of approximately 2000 loose-leaf pages is published each year in monthly issues. Subject and author indexes are compiled annually to cover abstracts issued from July through June. The yearly rate of \$50.00 includes two sturdy binders and index tabs.

An *Advance List*, a monthly bibliography of all reports received in this field, is available for \$10.00 a year.



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